TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

VOL. XV

JANUARY-DECEMBER

1920

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ILLUMINATING ENGINEERING SOCIETY
29 WEST THIRTY-NINTH STREET
NEW YORK, N. Y.

(ISSUED DEC. 30, 1920)

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XXI

MAJOR E. L. SHERWOOD.

Major Edward L. Sherwood was appointed Assistant Secretary of the Society, starting February 1st.

Major Sherwood has had considerable experience in the lighting field, as well as along other lines, which makes him particularly fitted for the position. From 1903 to 1913 he was employed by the General Electric Company in Schenectady, New York, and Harrison, doing shop and test work. In 1908 he organized the San Francisco district office of the Edison Lamp Works, in 1910 was assigned to the Cincinnati district. During the period of 1914-1918 he was a few months with the National Carbon Company, Cleveland, Ohio, and also a short time with the Merchant Engineers Corporation, New York City, as Chief Engineer. Later he became Production Manager and finally Manager of the New York Branch of the Abbott Motor Car Company, Detroit, Michigan, and Cleveland, Ohio.

During 1918-1919 Major Sherwood, having joined the U. S. Army, served as Commanding Officer of the Artillery Tractor Experimental Station, Detroit, Michigan, with rank of Captain. He was recommended for promotion in recognition of his suggestions for improving design of army tanks and tractors, and later was given the rank of Major U. S. R. Major Sherwood also designed for the army a new type of flash light battery with unlimited shelf life which was used by some departments of the army and was being considered for general adoption.

Since his discharge from active service last October, Major Sherwood was employed on the organization work in connection with Professional Sections for the American Society of Mechanical Engineers.

It is hoped that members will give Major Sherwood support in the work which he is undertaking for the Society in order that we may carry out our program.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV — FEBRUARY 10, 1920 — No. 1

COUNCIL NOTES.

ITEMS OF INTEREST.

Meeting—February 11, 1920.

Upon recommendation of the Board of Examiners the following were elected to membership:

Sixteen Associate Members.

J. H. ALLEN,
Street Lighting Specialist,
General Electric Co.,
Monadnock Bldg.,
Chicago, Ill.

EDWARD LYMAN BROWN,
Mgr. Incandescent Lamp Dept.,
Joseph E. Greene Co., Inc.,
111-115 Federal St.,
Boston, Mass.

FRED L. CARL,
Sales Engineer,
George Cutter Co.,
28 E. Jackson Blvd.,
Chicago, Ill.

DAVID DEUTSCHER,
Electrical Contractor,
256 Ryerson St.,
Brooklyn, N. Y.

THOS. A. DINEEN,
Mgr. Fixture Dept.,
Joseph E. Greene Co., Inc.,
111-115 Federal St.,
Boston, Mass.

WALTER A. FLEISHER,
Elec. Eng. and Purchasing Agt.,
S. B. & B. W. Fleisher, Inc.,
25th and Reed Sts.,
Philadelphia, Pa.

MILTON B. FIREHOCK,
Illuminating Engineer,
Cooper Hewitt Elec. Co.,
730 Grand St.,
Hoboken, N. J.

ARTHUR S. HUBBARD,
Sales Engineer,
Cooper Hewitt Elec. Co.,
161 Summer St.,
Boston, Mass.

GUY P. NORTON,
Assistant General Manager,
Duplex Ltg. Works of G. E. Co.,
6 West 48th St.,
New York, N. Y.

J. E. GREENE,
Pres., Joseph E. Greene Co., Inc.,
Jobbers in Electrical & Automobile Supplies,
111-115 Federal St.,
Boston, Mass.

J. H. KURLANDER,
Ass't. Illuminating Engineer,
Edison Lamp Works of G. E. Co.,
Harrison, N. J.

J. H. McGRAW,
Publisher,
McGraw-Hill Co., Inc.,
10th Ave. & 36th St.,
New York City.

H. G. OTIS,
New England Sales Mgr. & Elec. Engineer,
Cooper Hewitt Elec. Co.,
161 Summer St.,
Boston, Mass.

E. Y. Rice,
Elec. Engineer,
The Hartford Elec. Light Co.,
266 Pearl St.,
Hartford, Conn.

Edward W. Spitz,
Sales Engineer,
Duplex Ltg. Works of G. E. Co.,
6 W. 48th St.,
New York City.

Ben S. Willis,
Ass't. Physicist,
National Bureau of Standards,
Washington, D. C.

One Transfer to Membership.

Leonard E. Voyer,
Illuminating Engineer,
Edison Lamp Works,
San Francisco, Cal.

President Doane in suggesting to the Council a plan for closer co-operation between the Society and the larger industrial concerns with a common goal, that of discovering fields of research to determine the relation of better lighting to the stimulating of industrial production, recommended that a research committee be formed under the auspices and direction of the Society. That each Industrial concern participating should pay a portion of the expenses of the Committee, and the Society's work in this particular field. That the Committee be funded by the various industrial concerns represented, to the extent of $1000 per year per representative on the committee, and that the committee be a continuing one, that is: some representatives elected for one year, some for two and others for three years. The Council voted to investigate the possibilities of such a plan. President Doane appointed Mr. Clarence L. Law and Mr. Francis E. Cady to select other members to serve with them on this investigating committee.

The Council voted to endorse the project of the National Research Council to prepare and publish critical tables of physical and chemical constants.

The Council voted to request the Committee on Revision of Constitution and By-Laws to incorporate into the proposed revisions, an increase of 50 per cent. in annual dues of active and associate members, and to increase the maximum for a sustaining member to $500.

February 11th being the seventy-third anniversary of the birth of our esteemed Honorary Member, Thomas A. Edison, the Council telegraphed congratulations.

NEW COMMITTEE APPOINTMENTS

Committee on Time and Place.

Wm. J. Serrill, Chairman

H. K. Morrison	L. B. Marks
O. L. Johnson	Adolph Hertz
H. A. Hornor	John C. D. Clark
Wm. J. Clark	R. H. Maurer
Clarence L. Law	W. M. Skiff

Committee on Artistic Treatment of Interior Lighting.

Samuel G. Hibben, *Chairman,* to suggest names of at least two other members for this Committee.

SECTION ACTIVITIES.

CHICAGO.

Board of Managers, Chicago Section, met on February 6th, at Hamilton Club, Chicago—F. H. Bernhard presiding.

Plan to invite fixture manufacturers to February meeting, and architects to the May meeting and to arrange programs of special interest to their guests.

The proposed meetings of the Chicago Section for the remainder of the fiscal year are printed below:

March 18th—"How Artificial Light is Used by the Householder", by W. A. Durgin, Lighting Assistant to the Vice-President, Commonwealth Edison Co. The above title has not been furnished

by Mr. Durgin, but it is understood that such a title indicates roughly the tenor of his paper, which is based on an extensive survey being conducted by the Commonwealth Edison Company at this time.

April 15th—"New Aspects of Residence Lighting".—An illustrated lecture by M. Luckiesh, Physicist, Nela Research Laboratory. Original ideas will be presented putting residence lighting on a new plane.

May 13th—"School Lighting".—It is hoped that it will be possible to have Professor F. C. Caldwell of the Ohio State University present a paper on this subject, dealing particularly with childrens' eyesight, raising the utilization of investment in school buildings by the general use of school rooms in the evenings. It is hoped to call attention to the requirements of good school lighting, common faults, remedies, and the value of good example and precedence on the minds of children at a receptive age largely through actual school lighting installations of a high order.

NEW YORK.

Meeting—February 19, 1920.

A successful joint meeting of the New York Section of the Illuminating Engineering Society and the Society of Gas Engineering of New York City, was held at the Auditorium, Consolidated Gas Building, 130 E. 15th St., New York, on February 19, 1920. There were about seventy-five in attendance, representing both Societies.

Mr. Motoo Uchisaka, Secretary, Illuminating Society of Japan, presented a very interesting and instructive paper, entitled, "Artificial Lights and Their fixtures in Japan". The paper treated briefly of the development of civilization in Japan and its influence on lighting fixtures, and was illustrated by about forty slides. This was followed by a description of lighting developments from the time of the camp-fire to modern times.

The Chairman of the Papers Committee gave an outline of the meeting for March. Two papers will be presented. One on Railroad Signals, by Messrs. Stallnecht and Porter, and the other on The Developments of Sign Lighting, by Mr. E. A. Mills.

PHILADELPHIA.

Meeting—January, 1920.

The monthly meeting was held on January 16, 1920, at 8:00 P. M., at the Engineers' Club, 1317 Spruce Street. Mr. Regar opened the meeting and introduced Dr. Howard Lyon, of the Welsbach Company, who gave the first of a series of talks on the "Elementary Principles of Illumination for the Practical Man". He explained with models the units used in measuring light. This series of talks will be continued at the coming meetings.

Mr. M. Luckiesh, of the Nela Laboratories, then gave a talk on "School Lighting". The importance of attention to this subject is indicated by records of the examination of the pupils' eyes, made through a period of years, these records showing progressive short-sightedness as the pupil advances. The ability to control artificial light makes it under many conditions preferable to daylight, and it is quite probable that the number of places now lighted by both, as the years pass will discard the use of daylight altogether. The legislation covering the lighting of schools exists in only a few states, and in many cases is vague or inconsistent. However, there are indications that more attention is constantly being paid to the subject, and it is probable that much good will result therefrom in Philadelphia.

Forty-five persons attended the meeting. The preliminary dinner was held at the Arcadia Cafe, and twenty-three were present.

Meeting—February, 1920.

The monthly meeting of the Philadelphia Section was held at the Engineers' Club of Philadelphia, 1317 Spruce Street, at 8:00 P. M., on February 20th, 1920.

Dr. Howard Lyon gave the second of his series of talks on "Elementary Principles of Illumination for the Practical Man".

Mrs. Mary Hallock Greenewalt described the thoughts underlying the association of light with music, exhibited the latest model of her light scale keyboard with rheostat, and executed a medley of music and light on a "light phonograph".

The paper of the evening was presented by Mr. Norman Macbeth, illuminating engineer of the Artificial Daylighting Company, New York, on "Artificial Daylighting Equipment". Mr. Macbeth told of the increasing importance and application of artificial daylight to many industrial and business operations, and of the means used to produce it. His talk was illustrated with lantern slides and was unusually interesting to both the technical man and the layman. The discussion produced some interesting facts. The attendance at the meeting was 62.

The dinner preceding the meeting was held at the Arcadia Cafe. Fifteen were present.

March 19, 1920.

"Development of the R. L. M. Standards for Industrial Lighting"—(Illustrated with Lantern Slides.) By Ward Harrison, Illuminating Engineer, National Lamp Works, Cleveland, Ohio.

"Residence Lighting" — (Illustrated with Lantern Slides.) By M. Luckiesh, Physicist, Nela Research Laboratories, Cleveland, Ohio.

(This meeting will be under the auspices of the Washington Section A. I. E. E.)

April 16, 1920.

"Daylight Saving"—(Illustrated with Lantern Slides.) By Preston S. Millar, General Manager, Electrical Testing Laboratories, New York.

May 21, 1920.

"Color Photography" — (Illustrated with Motion Pictures.) By Henry Hess, Hess-Ives Corporation, Philadelphia, Pa.

Highland Park, Pa.

June 14, 1920.

Joint Outing with the Philadelphia Section, American Institute of Electrical Engineers at the Howard McCall Field.

NEW ENGLAND.

Meeting February 27, 1920, at Engineers' Club, Boston. Speaker—Dr. Howard Lyon, Wellsbach Company, Philadelphia. Lecture on Fundamentals of Illumination. Dr. Lyon's lecture will be illustrated with models. It is expected that President Doane will attend.

NEWS ITEMS.

President Doan speaks on illumination at two meetings of Yale Branch, American Institute of Electrical Engineers including invited guests from the American Society of Mechanical Engineers and the Illuminating Engineering Society.

The meetings were held at Dunham Laboratory of Electrical Engineering, New Haven, Conn. February twenty-fourth, President Doane's afternoon address was on Illumination and its relation to the arts, sciences and profes-

sions. It develops the general field of Illumination and Illuminating Engineering, and brings out their intimate relation to other arts and sciences.

Illuminating Engineering he said is in close relation with more varying subjects of arts and sciences than any other profession; as a consequence, these other arts, sciences and professions should be informed as to the points of common interest.

Illuminating Engineering touches upon psychology, medicine (or at least physiology and the pathology of radiant energy). It has to do with architecture, with art and industrial production, with law and the legal requirements imposed upon lighting companies; it is dependent upon the laws of physics; hence, an Illuminating Engineer is a physicist to some extent, an Electrical Engineer when his source of light is by electrical energy, or to an extent, a Gas Engineer when the source of light is from gas.

In the evening, President Doane discussed the subject of Illumination in industry, its relation to production and the economical results, giving his impressions resultant from some recent quantitative studies on the economy and all the related factors which contribute to this economy of efficient illuminating installations in factories. The psychology, the personal element, the reasons for the results, related and analyzed.

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Present Status of the "Shōmei Gakkwai" Illuminating Engineering Society of Japan.

By Motoo Uchisaka.

With a view to conducting scientific research in lighting, and the application of lighting in public and private enterprises, the Japanese Society is publishing a journal of their transactions, *"Shomei Gakkwai zasshi"*, and during the first half of 1919, two issues were printed.

No. 1, March 30, featuring Artistic Electric Lighting Fixtures, by T. Adachi. Typical Curves of Light Distribution, by Y. Yoshioka.

No. 2, June 30, featuring Searchlights, by Major S. Uchida. Notes on Beck Searchlight, by Y. Murakami. Measurement of Spherical Reduction Factors of Incandescent Electric Lamps, by M. Igari. Report on Electric Lamp Standardization Specification for Tungsten Filament Lamps.

Lectures.

Lecture-meetings were held at the Gakushikai Building, Kanda, Tokyo City, on January 30, and May 2, 1919.

Committees.

Among the committees of the Society, are

STANDARDIZATION OF ELECTRIC LAMPS
NOMENCLATURE
MEMBERSHIP
SCHOOL LIGHTING
STREET LIGHTING
FACTORY LIGHTING
FACTORY LIGHTING

The Society is considering the offering of prizes for new designs of Illuminating apparatus.

The Society has 690 members, comprising

1 Honorary Member (Dr. G. Yamakawa, Past President)
110 Sustaining Members
543 Active Members
36 Associate Members

an increase of 5 per cent. over previous year.

The President of the Society is Dr. O. Asano, Hon. Professor, Tokyo Im-

perial University. Vice-Presidents, Dr. D. Nakahara, Vice-President Tokyo Electric Light Co., Y. Shinjo, President, Tokyo Electric Co.

Managers—

T. Hatano, Vice-President, Dai Nippon Electric Lamp Co.

Dr. T. Kujirai, Professor, Electrical Engineering College of the Tokyo Imperial University.

R. Mitsuda, Electrical Engineer, Imperial Communication Department.

S. Otahara, Electric Engineer, Tokya Municipal Electricity Bureau.

M. Tsukasaki, Electrical Engineer, Tokyo Electric Co.

M. Uchisaka, Illuminating Engineer, Tokyo Electric Co.

Besides these officers, there are 38 Councillors, who participate in the management of this Society.

Home Lighting Lecture

The Department of Architecture, University of Illinois, Urbana, Illinois, write as follows:

"We found the manuscript and lantern slides sent us to illustrate the lecture on Home Lighting, exceedingly interesting, and trust that we may have the advantage of their use again at a later date."

The General Office take this opportunity to state that this Standard lecture and others are available upon request.

Professional Opportunities.

Industrial physicists. An established research laboratory of a well-known manufacturer offers positions to qualified scientific men who have research ability. One or two men of scientific training in physics and experience in research are desired. There is also a position open for a physicist with less experience but with creative ability. Working conditions are attractive and positions are permanent.

Location, Ohio. Z-558

An engineer with creative and analytical ability and pleasing personality is desired by a laboratory interested chiefly in the development of lighting. Some experience in lighting is desirable, though not essential. A permanent position amid pleasant surroundings awaits one who can qualify.

Location, Ohio. Z-559

Young Illuminating Engineer. Capable of designing show windows and commercial lighting installations: selling experience desirable but not essential.

Location, Tennessee. Z-260

Illuminating Engineer wanted by large Electrical Contractor in important Canadian city, experienced in industrial work and with sales ability. Construction experience desirable but not essential. Would prefer man willing to work on salary and commission.

Z-584

Old Copies Wanted.

Wanted—a few copies Volume XIV, No. 2, of March 20th, 1919.

General Office will pay fifty cents ($0.50) per copy.

Books.

Electric Lighting—OLIN J. FERGUSON, M. S.—published by the McGraw-Hill Book Company, New York, 1920. 238 pages, illustrated, table of contents and index.

A popular book on the subject of general lighting practice—including wiring and apparatus, types of lamps, physics of lighting, photometry, color, illumination calculation, etc.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

Journal of the A. I. E. E.		1920	
The Series System of Street Lighting Distribution—	W. P. Hurley	Jan.	1
Multiple Systems of Distribution for Street Lighting—	Ward Harrison	Jan.	7
Pure Science and Industrial Research—	J. J. Carty	Jan.	57
Journal of Electricity			
General Lighting Safety Orders—		Jan. 1	30
Industrial Lighting—	Editorial	Jan. 1	4
Journal of the Franklin Institute			
Hypersensitizing Commercial Panchromatic Plates—	Samuel M. Burka	Jan. 1	25
Nature		1919	
The British Association and Scientific Research—		Nov. 27	337
Physical Review			
The Spectral Photoelectric Sensitivity on Molybdenite as a Function of the Applied Voltage—	W. W. Coblentz and H. Kahler	Dec.	534
Psychobiology		1918	
The Influence of the Distribution of Brightness over the Visual Field on the Time Required for Discriminative Responses to Visual Stimuli—	H. M. Johnson	May	459
Revue Generale de L'Ectricite		1919	
Un Nouvel arc a mercure a allumage automatique—	Henri George	Dec. 6	815
Science		1920	
The Organization of Research—	H. P. Armsby	Jan. 9	33
Scientific American Monthly			
Luminous Living Creatures—	Raphael Dubois	Jan. 1	9
The Effects of Light on Plants—	Fritz Schanz	Jan. 1	12
Scientific American Supplement		1919	
Disadvantages of the Use of Protective Fittings of High Candle-power Incandescent Electric Lamps—		Dec. 27	383
Improvement in the Illumination of Railway Signal Lamps—		Dec. 27	385
Trans. of the I. E. S.			
Report of the Committee on Progress—		Nov. 20	313
How to make Home Lighting Comfortable and Effective—	A. L. Powell and R. E. Harrington	Nov. 20	394

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV MARCH 20, 1920 No. 2

COUNCIL NOTES.

ITEMS OF INTEREST.

Meeting—March 11, 1920.

Upon recommendation of the Board of Examiners the following were elected to membership:

Five Associate Members.

JOHN G. ADDY,
Electrical & Illuminating Engineer,
1453 East Tenth Street,
Brooklyn, N. Y.

ARTHUR N. MARTINSON,
Commercial Engineering Dept.,
Westinghouse Lamp Co.,
Bloomfield, N. J.

JAMES D. HALL,
Commercial Engineering Dept.,
Westinghouse Lamp Co.,
Bloomfield, N. J.

PROFESSOR OLIN JEROME FERGUSON,
University of Nebraska,
Lincoln, Nebraska.

ALLEN A. TIRRELL,
Electrical Engineer,
404 Richland Street,
Homewood, Pennsylvania.

One Transfer.

HERBERT FAIRFAX WALLACE,
Edison Lamp Works, General Electric Co.,
84 State Street,
Boston, Mass.

NEW COMMITTEE APPOINTMENTS

Committee on Nomenclature and Standards.—A. E. Kennelly, Chairman, C. H. Sharp, Sec'y., Louis Bell, C. O. Bond, E. C. Crittenden, W. A. Dorey, E. J. Edwards, E. P. Hyde, C. O. Mailloux, W. E. Saunders, C. P. Steinmetz, A. S. McAllister.

Committee on Progress.—F. E. Cady, Chairman, W. B. Lancaster, F. R. Mistersky, O. H. Fogg, W. E. Saunders.

Committee on Membership Drive Planning.—P. S. Young, L. B. Marks, C. L. Law, F. M. Feiker, F. W. Prince.

REPORTS OF COMMITTEES.

Report of Committee on Industrial Applications of New Lighting Developments.—Mr. Cady reported that the committee had come to two conclusions; first, that this was essentially a problem of pure Research therefore that it would be a function of the Research Committee; second, that inquiry be made whether this would in any way interfere with the work the National Research Council is carrying on; that Professor C. A. Adams, as Chairman, Division of Engineering, National Research Council, had said that he did not think it would conflict in any way with the work of any other society and the National Research Council would like to be kept informed of what was being done. In the past the Research Committee of the Society

had tried to stimulate Research; never to carry on Research.

This Committee should get in touch with large industrial concerns and ascertain what recommendations they would offer as a result of their experience; inform them that the Society had a committee to act as an intermediary; that they be invited to appoint members; that they be invited to contribute to the support of the Society.

The Committee recommended that a Research Committee be appointed under that name.

The report was accepted and the committee discharged.

Mr. Stickney, Chairman of Committee on Revision of Constitution & By-Laws, made a progress report of the work done by this committee.

Report of Committee on Nominations.—Mr. G. H. Stickney, Chairman, reported that the Committee at their meeting held on the afternoon of February 18, 1920, unanimously selected the following nominees:

For President: General George H. Harries.

For General Secretary: Clarence L. Law.

For Treasurer: Louis B. Marks.

For Vice-Presidents: New England Section, H. F. Wallace; Philadelphia Section, G. S. Crampton; Chicago Section, J. J. Kirk.

For Directors: Adolph Hertz, Walton Forstall, Frank S. Price.

That each of the nominees had been approached and had signified his willingness to serve.

NEW PUBLICATIONS SUGGESTED.

Consideration of the Publication by the Society of a Lighting Handbook and a Complete Index and Cross Index of Transactions was Recommended by the New York Section. Upon resolution of the Council this matter was referred to a special committee to consider and report recommendations to the Council Committee as follows:

Preston Millar, *Chairman*
G. H. Stickney
L. B. Marks

Code of Fixture Design.

At the request of the New York Section the Council is considering the preparation of a code of fixture design. This matter was referred to the Committee on Lighting Legislation for their recommendation.

DRIVE FOR MEMBERSHIP.

The General Secretary proposed a Membership Drive to be handled from the General Office and executed by a large Committee composed of Chairmen representing various Central Stations, both Gas and Electric, Gas Lighting Appliance Manufacturers and Distributors, Manufacturers of Lighting Apparatus, etc.

This Committee to be supported by numerous Sub-Committees, reaching down to actual contact with the prospects for Membership.

It is estimated that the personnel of the General Committee and its Sub-Committees will approximate several hundred men.

Suggestion was also made that Sections and proposed Local Chapters be encouraged to govern their own finances and activities, that this will help provide for reasonable growth and will tend to keep our present members interested and active.

A Committee was appointed to plan for the drive and other committees will be appointed later, both general and local, to carry on the active work.

SECTION ACTIVITIES.

CHICAGO.

Monthly Meeting, March 17, 1920.

Held in Western Society Rooms, Monadnock Building; F. H. Bernhard presided. There were in attendance 50 members and 100 guests.

Speakers: W. A. Durgin, Lighting Asst. to Vice President, Commonwealth Edison Company, Chicago. Motoo Uchisaka, Illuminating Engineer, The Tokyo Electric Co., Tokyo, Japan.

Subjects: "Our Perennial Travesty—Home Lighting." "Artificial Lights and Their Fixtures in Japan."

Mr. Durgin's paper gave a survey of the data obtained in 750 Chicago homes of all classes, contrasted with prevailing theories, together with an examination of the reasons for this contrast and some suggestions of particular interest to the

Landlord	Architect
Home-maker	Decorator
Fixture Dealer	Central Sta. Mgr.
Wiring Contractor	Illum. Engineer

The lamp, fixture and appliance situation detailed as found; also the illuminating and service conditions that prevailed. These were compared with the literature of the Illuminating Engineering Society on this subject for the past several years; also the literature of the fixture manufacturers and dealers. A large number of slides were shown, also demonstrations of typical lighting equipment removed from Chicago homes and lighted and displayed in an appropriate booth. Examples of what the fixture dealers are recommending to the public were also shown in the booth.

Mr. Uchisaka distributed printed copies of his paper but excused himself from reading it.

A very active discussion followed Mr. Durgin's paper, particularly on the part of the fixture manufacturers and dealers present, one of whom is closely associated with the National Fixture Council, so that some results may be looked for in this direction.

Members of the section and guests dined at the city club prior to the meeting.

April 15th—"New Aspects of Residence Lighting".—An illustrated lecture by M. Luckiesh, Physicist, Nela Research Laboratory. Original ideas will be presented putting residence lighting on a new plane.

May 13th—"School Lighting".—It is hoped that it will be possible to have Professor F. C. Caldwell of the Ohio State University present a paper on this subject, dealing particularly with childrens' eyesight, raising the utilization of investment in school buildings by the general use of school rooms in the evenings. It is hoped to call attention to the requirements of good school lighting, common faults, remedies, and the value of good example and precedence on the minds of children at a receptive age largely through actual school lighting installations of a high order.

NEW YORK.

Meeting—March 11th, 1920.

Two papers were presented. One on Railroad Signals, by Messrs. Stallknecht and Porter, and the other on The Developments of Sign Lighting, by Mr. E. A. Mills. Both were extremely interesting and were read before a large attendance.

At a meeting of Board of Managers, New York Section, held at the Society's Rooms on February 26th, 1920, follow-

ing nominating committee was appointed:

W. T. BLACKWELL, *Chairman*
F. M. FEIKER
J. P. RADCLIFFE, Jr.
D. McFARLAN MOORE
C. L. LAW
F. K. BARNITZ

Mr. Blackwell brought up the question of a lighting hand book which could be prepared by the Society and furnished at a nominal charge to any parties that might be interested in the subject. This handbook could be made up in two forms, one bound, and the other loose leaf. The latter form could be supplied to manufacturers who got out catalogues and could readily be made a part of their catalogue. It was felt that such a handbook would, in addition to giving prestige to the Society, form a means of some additional income. Such a hand book would perhaps become more authoritative than some of the hand books published by manufacturers due to the fact that there would be no commercialism attempted.

April Meeting.

Papers: "Searchlights in the A. E. F." By Doraf Wilmot Blakeslee, formerly First Lieutenant, 56th Engineers, A. E. F.

"Historical Sketch of Street Lighting." By P. S. Millar, Electrical Testing Laboratories.

Time: Thursday evening, April 8, at 8 P. M.

Place: Engineering Society Building, 29 West 39th Street, New York City.

Dinner: An informal a la carte dinner will be held at Healy's Restaurant, 42nd Street and Madison Avenue, at 6:15 P. M.

Other meetings scheduled for May 13th and June 10th.

PHILADELPHIA.

Meeting—March 19th, 1920.

The monthly meeting of the Philadelphia Section was held in the ballroom of the New Willard Hotel, Washington, D. C., on March 19, 1920, at 8:00 P. M., under the auspices of the Washington Section, American Institute of Electrical Engineers. The meeting was opened by Mr. Flanders, Chairman, A. I. E. E., who welcomed the visiting delegation and then resigned the chair in favor of Mr. G. Bertram Regar, Chairman, Philadelphia Section, I. E. S.

The first paper was by Mr. Ward Harrison, Illuminating Engineer, National Lamp Works of the General Electric Company, Cleveland, Ohio, on "Development of R. L. M. Standards for Industrial Lighting." The second paper was by Mr. M. Luckiesh, Physicist, Nela Research Laboratory, National Lamp Works, Cleveland, Ohio, on "Residence Lighting." Both papers were well presented, illustrated with lantern slides, and of real interest to the audience. The attendance was about one hundred and seventy-five (175).

This was the first occasion on which the Philadelphia Section has held a meeting in Washington, and its great success should serve to make this a permanent feature of every year's program.

April 16, 1920.

"Daylight Saving"—(Illustrated with Lantern Slides.) By Preston S. Millar, General Manager, Electrical Testing Laboratories, New York.

May 21, 1920.

"Color Photography" — (Illustrated with Motion Pictures.) By Henry Hess, Hess-Ives Corporation, Philadelphia, Pa.

Highland Park, Pa.

June 14, 1920.

Joint Outing with the Philadelphia Section, American Institute of Electrical Engineers at the Howard McCall Field.

NEW ENGLAND.

The February meeting of the Section was held at the Engineers' Club on Friday, February 27th, the speaker of the evening being Dr. Howard Lyon of the Welsbach Co., Gloucester, New Jersey.

He spoke on the Fundamentals of Illumination. This lecture was similar in character to one previously delivered in Philadelphia. Dr. Lyon handled his subject in a masterly way and the lecture was productive of much beneficial discussion.

Following Dr. Lyon's discussion, President Samuel E. Doane of Cleveland delivered a greeting from the general society to the Section.

In spite of severe and inclement weather a large and representative crowd was present.

PROFESSIONAL OPPORTUNITIES.

Engineer with broad experience in illuminating field, should be posted on development of methods of illumination measurements and design of apparatus for such measurements, the direction of special illumination testing, the design of units, the selection of lamps for special work such as is encountered in various signal systems, development of home and farm lighting outfits.

Location, Northern New Jersey, near New York. Z-940

We desire men having a knowledge of illuminating engineering. Experience is the principal point. In order to be of any use they must be familiar with modern illuminating engineering practice and be able to design lighting layouts as field engineers. Salary depends largely upon the experience. We are willing to pay well for good men.

Location Newark, N. J. Z-872

Industrial physicists. An established research laboratory of a well-known manufacturer offers positions to qualified scientific men who have research ability. One or two men of scientific training in physics and experience in research are desired. There is also a position open for a physicist with less experience but with creative ability. Working conditions are attractive and positions are permanent.

Location, Cleveland, Ohio. Z-558

An engineer with creative and analytical ability and pleasing personality is desired by a laboratory interested chiefly in the development of lighting. Some experience in lighting is desirable, though not essential. A permanent position amid pleasant surroundings awaits one who can qualify.

Location, Cleveland, Ohio. Z-559

Illuminating Engineer wanted by large Electrical Contractor in important Canadian city, experienced in industrial work and with sales ability. Construction experience desirable but not essential. Would prefer man willing to work on salary and commission.

Z-584

Old Copies Wanted.

Wanted—a few copies of the following issues of "TRANSACTIONS."

General Office will pay fifty cents ($0.50) per copy.

Volume One—
- No. 1
- No. 2
- No. 3
- No. 8
- No. 9

Volume Two—
- No. 1
- No. 3
- No. 4

Volume Three—
- No. 1
- No. 2
- No. 4

Volume Eight—
- No. 7
- No. 8
- No. 9

Volume Nine—
- No. 2

Volume Ten—
- No. 8

NEWS ITEMS.

PERSONAL MENTION.

F. H. Bernhard, chairman of the Chicago Section, has recently resigned as managing editor of the *"Electrical Review"* to become editor of the "E. M. F. *Electrical Year Book."*

Mr. Bernhard is a graduate of the Armour Institute of Technology, Class of 1901. He is an Electrical Engineer, —his early experience was with the Helios-Upton Company, on storage battery work. Later he returned to Armour Institute where he served for over four years as instructor of electrical engineering. During the past twelve and one-half years has been on the editorial staffs of the *"Western Electrician," "Electrical Review* and *Western Electrician"* and *"Electrical Review"* in various capacities, and as managing editor of the *"Electrical Review"* at the time of his resignation.

L. Leroy Gritzan is now associated with Claude B. Hellmann Company, 403 North Charles Street, as illuminating engineer.

GOOD LIGHTING AND PRODUCTION.

Ward Harrison, Chairman of the Committee on Reciprocal Relations, will present a paper before the meeting of the Taylor Society at Rochester, New York, May 7th, showing the relation of good lighting to increased industrial production, and how the illuminating Engineering Society can be helpful to the Production Engineer.

CODE OF SCHOOL LIGHTING.

Thomas Lloyd Jones, chairman of Committee on High School Relations of the University of Wisconsin, writes that he is very much impressed with the Code of Lighting School Buildings; that in his travels from school to school, he is painfully impressed with the fact that the average builder and architect apparently have given but slight attention to the subject of illumination, and that the Code of School Lighting is likely to be of great benefit to many Wisconsin boys and girls.

RESEARCH.

At a recent meeting of the Council, the President suggested the idea that members present questions for research work which the Society could undertake to consider. It was thought that questions such as glare, relation of proper lighting to working conditions and such like could be submitted to colleges and universities to form a thesis of this work. Members who have any suggestions which might be considered in this direction are asked to forward them to the General Secretary. We have had

some suggestions and hope to have more.

LEGIBILITY OF COLORS.

The following list gives the order of legibility for various combinations of colored printing and colored paper—the distance from the eye, the size and form of type and other factors being the same in each case. Note that ordinary black and white occupies fifth place.

1. Black letters on yellow paper.
2. Green letters on white paper.
3. Blue letters on white paper.
4. White letters on blue paper.
5. Black letters on white paper.
6. Yellow letters on black paper.
7. White letters on red paper.
8. White letters on green paper.
9. White letters on black paper.
10. Red letters on yellow paper.

We believe the above has probably come to the attention of our members from other sources, but the list here given is reprinted from "Good Will."

ELECTRIC LIGHTING IN ENGLAND.

In the area of London alone, are 70 authorities that supply electricity to the public, owning 70 generating stations, with 50 different types of systems, 10 different frequencies, and 24 voltages.

The average generating capacity of the 600 establishments in England that sell electric current is only 5,000 horse-power each. This is about one-fourth the capacity of a generating plant of economical size. So unorganized is the whole electrical industry that "one can not purchase a simple electric bulb without specifying the particular type of socket" in which it is to be used. There is a strong movement in England today to divide the entire country into 16 power zones, under the control of the Government, and gradually to replace existing plants by 16 superpower stations, capable of supplying industrial power to the whole of England.

[*Quoted from Department of Commerce Bulletin of February 17th.*]

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Doherty News			
Illumination of Danbury, Conn.—	News Item	Feb.	30
Electrical Merchandising			
The Lighting Fixture with an Aim—	M. Luckiesh	Jan.	37
New Flexible System of Wiring and Lighting—	News Item	Feb.	101
Electrical News (Canada)			
Lighting the Home—		Feb. 1	42
The Field of Electric Lighting is Unlimited—Proper Illumination Exerts a Big Physical Influence—Some brief Suggestions for Layout in Various Rooms—		Feb. 15	40
The Value of Proper Illumination—In Stores, Factories Homes—Insidious Effects Due to Bad Lighting—		Mar. 15	37
Electrical Record			
Prince of Wales Inaugurates Flood Lighting of Canadian Falls at Niagara—	News Item	Jan.	20
Electrical Review (U. S.)			
Survey of Prevailing Conditions as to Industrial Lighting, II—		Jan. 31	180
Survey of Prevailing Conditions as to Industrial Lighting, III—		Feb. 7	222
Maintenance of Interior Lighting Systems—	A. L. Powell	Feb. 14	263
Lighting of Power Plants and Substations—	Editorial	Feb. 14	276
Wisconsin Proposes New Laws for Automobile Lamps—	Editorial	Feb. 14	281
Electrical Times (London)			
Paint and Illumination—		Dec. 25	506
Modern Street Lighting—		Jan. 15	52
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Keeping Up the Illumination—	Editorial	Jan. 31	250
The Effect of Lighting on Accidents—		Jan. 31	259

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Street-Lighting Service for Relatively Large City—		Feb. 7	325
The Westcott System of Factory Lighting (abstract from Elektrotechnische Rundschau, July 28, 1919)—		Feb. 7	3341
Photometric Measurements on Searchlights (abstract from Zeitschrift fur Beleuchtungswesen, April, 1919)—		Feb. 7	334
Industrial Lighting Codes—		Feb. 14	378
Trying Daylight Saving on a Partial Scale—		Feb. 21	419
Interiors Illuminated Without Ceiling Fixtures—		March 6	551
National Popularization of Lighting Proposed—		March 6	567
Nation in Throes of Local Daylight-Saving Decision—		Mar. 27	745
Electrician			
Carbon Arcs for Searchlights—		Dec. 19	730
Renewed Lamps—		Dec. 26	750
Street Lighting in Hackney—		Jan. 2	16
The Science of Colour Matching—	Editorial	Feb. 6	134
Elektrotechnische Zeitschrift			
Die Fernschaltung und Fernuberwachung der offentlichen elektrischen Beleuchtung in Charlottenburg—	W. Jordan, J. Kuhlo	Jan. 1	8
Gas Journal			
Flat-Flame Lighting—		Jan. 6	26
Early Days of Gas in the Old Kent Road—		Feb. 24	431
General Electric Review			
Improving the Mazda Automobile Headlight Lamp—	L. C. Porter	Jan.	67
An Absolute Method for Determining Coefficients of Diffuse Reflection—	F. A. Benford	Jan.	72
Effect of Color of Walls and Ceilings on Resultant Illumination—	A. L. Powell	Mar.	209
Illuminating Engineer (London)			
Lambert and Photometry—	A. P. Trotter	Nov.	313
Report of the Committee on Progress in Lamps and Lighting Appliances—		Nov.	319
The Sheringham "Daylight"—	L. C. Martin	Nov.	323
New Forms of Pointolite Lamps—	P. Freedman	Nov.	324

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A New Form of Illumination Photometer—	Haydn T. Harrison	Nov.	328
Natural and Artificial Lighting in Factories—	Editorial	Dec.	334
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Early Use of Gas for Lighting on Festive Occasions—		Dec.	343
The Measurement of Shadow—		Dec.	344
Journal of Electricity			
Lighting of Broadway, Los Angeles—	News Item	Mar. 15	288
New Application of Theater Lighting Effects—	News Item	Mar. 15	289
Lighting—	Editorial	Feb. 15	150
New Intensive Street Lighting—	W. D'A. Ryan	Feb. 15	151
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Daylight Saving—	Preston S. Millar	Feb.	146
Journal of the Franklin Institute			
The Relative Merits of Monocular and Binocular Field-Glasses—	Edward P. Hyde, P. W. Cobb, H. M. Johnson and W. Weniger	Feb.	185
Moving Picture World			
Psychology of Colored Lights is Explained in Application to Signs—		Feb. 21	1226
Nature			
Industrial Research—	A. P. M. Fleming	Jan. 8	470
Industrial Research Associations—		Jan. 22	551
Luminosity in Centipedes—		Feb. 26	705
Photographic Journal			
Get It in the Lighting—		Feb.	49
Railway Electrical Engineer			
Maintaining and Operating Electric Headlights—		Jan.	13
Revue Generale de L'Electricite			
Les variations de tension admissibles avec les lampes electriques a filament metallique (Elektro industrie, Mai 1, 1919)—		Dec. 13	174D
Les projecteurs electriques pendant la guerre—	Marius Grosjean	Dec. 13	174D
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Co-operation in Research—	Dr. George Ellery Hale	Feb. 13	149
Transactions of the I. E. S.			
Symposium—Application of Industrial Lighting Codes—		Dec. 30	435
U. S. Monthly Weather Review			
Variation in the Total and Luminous Solar Radiation with Geographical Position in the United States—	H. H. Kimball	Nov.	769
Bibliographic Note on Sunshine in the United States—	R. DeC. Ward	Nov.	794
A New Instrument for Measuring Sky Radiation—	A. Angstrom	Nov.	795
Some Problems Relating to the Scattered Radiation from the Sky—	A. Angstrom	Nov.	797

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV APRIL 30, 1920 No. 3

SECTION ACTIVITIES.

CHICAGO.

Meeting—April, 1920.

Monthly meeting was held in the rooms of the Western Society of Engineers on April 21st at 7 P. M. "Light and the Householder" was the paper of the evening presented by M. Luckiesh. Mr. Luckiesh described how light may be used to beautify and decorate the home, and encourages central station men and fixture dealers to dwell upon the artistic possibilities of illumination in their suggestions to the householder.

May 13th—"School Lighting."—It is hoped that it will be possible to have Professor F. C. Caldwell of the Ohio State University present a paper on this subject, dealing particularly with children's eyesight, raising the utilization of investment in school buildings by the general use of school rooms in the evenings. It is hoped to call attention to the requirements of good school lighting, common faults, remedies, and the value of good example and precedence on the minds of children at a receptive age largely through actual school lighting installations of a high order.

Report of Nominating Committee appointed by the Chairman to nominate section officers for Chicago is given below:

Chairman—J. L. Stair
Secretary—J. J. Kirk
Board of Managers—
F. F. Fowle
J. W. Foster
E. D. Tillson
F. T. Benson
A. T. Hunt

NEW YORK.

Meeting—April, 1920.

The monthly meeting was held on April 8th at 8 P. M. at the Engineering Societies Building being preceded by an informal dinner at Healy's Restaurant. The papers of the evening as follows, were especially interesting and appear in this issue of TRANSACTIONS. "Searchlights in the A. E. F.," by D. W. Blakeslee, former 1st Lieutenant, 56th Engineers, and "Historical Sketch of Street Lighting," by Preston S. Millar.

The next meeting will be held on May 13th at the same time and place. The paper of the evening will be "Illuminating Engineering from the Side Lines," by R. W. Shenton, National Lamp Works, Cleveland. Dinner at Healey's as usual.

Report of Committee on Nominations:

Chairman, W. T. Blackwell of the New York Section Nominating Committee, reported the following nominations:

Chairman—R. E. Myers
Secretary—Schuyler W. Van Rensselaer

Board of Managers—
C. A. Franck
H. V. Bozell
F. R. Barnitz
Herman Plaut
C. A. Barton

PHILADELPHIA.

Meeting—April, 1920.

The monthly meeting of the Philadelphia Section was held in the auditorium of the Engineers' Club, 1317 Spruce Street, on April 16, 1920, at 8:00 P. M., preceded by an informal dinner at the Engineers' Club.

The chairman called the attention of the members to the fact that the paper at the May Meeting will be on "Color Photography," and stated the decision to make this a Ladies' Night. Also that the June Meeting will be a joint "get together" meeting with the local section of the American Institute of Electrical Engineers, and will be held during the afternoon and evening on the athletic field of the Philadelphia Electric Company.

The chairman of the Membership Committee announced that the Council has authorized a special drive for new members, and to encourage this, has suspended the payment of the initiation fee and has authorized the yearly dues for members joining after April 1st, as one-half of the full yearly dues. The members were requested to make further efforts to increase our membership.

Dr. Howard Lyon gave the third of his interesting series of talks on "Elementary Principles of Illumination."

The paper of the evening was presented by Mr. Preston S. Millar, General Manager, Electrical Testing Laboratories, New York, on "Daylight Saving." Mr. Millar covered this subject from every angle and a surprising feature of the resultant discussion was the statement, made by several gentlemen, that they had been converted from daylight saving adherents to its opponents, by the common sense data that had just been presented to them.

May 21, 1920.

"Color Photography" — (Illustrated with Motion Pictures.) By Henry Hess, Hess-Ives Corporation, Philadelphia, Pa.
Highland Park, Pa.

June 14, 1920.

Joint Outing with the Philadelphia Section, American Institute of Electrical Engineers on the athletic field of the Philadelphia Electric Company.

Report of Committee on Nominations:

Chairman—Prof. C. E. Clewell
Secretary—H. B. Anderson
Board of Managers—
Dr. Howard Lyon
G. Bertram Regar
Herman Eckstein
C. S. Snyder
J. B. Kelley

NEW ENGLAND.

Meeting—April, 1920.

Monthly meeting was held April 16th in the rooms of the Engineers' Club, Boston. "The Reproduction of Daylight and Its Use," by Norman Macbeth, and "The Development of Army Searchlights and Metal Mirrors," by C. A. B. Halvorson, were the papers of the evening.

Report of Committee on Nominations:

Dr. Louis Bell, Chairman, Committee on Nominations for New England Section, reports nominations as follows:

Chairman—N. W. Gifford
Secretary—J. T. Kerens
Directors—
J. W. Cowles
F. A. Gallagher, Jr.
L. T. Troland
C. M. Halstead
David Crownfield

COUNCIL NOTES.

ITEMS OF INTEREST.

Meeting—March 11, 1920.

Upon recommendation of the Board of Examiners the following were elected to membership:

One Member.

L. A. S. Wood,
Electrical Engineer,
George Cutter Co.,
South Bend, Indiana.

One Associate Member.

Benjamin G. Eynon,
State Registrar of Motor Vehicles,
State Highway Dept.,
201 North Second Street,
Harrisburg, Pa.

Three Transfers.

B. F. Fisher,
Consulting Engineer of Mazda Service,
General Electric Company Research Laboratory,
Schenectady, N. Y.

Charles Franck,
Holophane Glass Co., Inc.,
340 Madison Avenue,
New York, N. Y.

G. Brewer Griffin,
Manager Automobile Equipment Dept.,
Westinghouse Electric & Manufacturing Co.,
110-114 West 42d St.,
New York, N. Y.

Meeting—April 8, 1920.

Eight Members.

Ephraim S. Hamblen,
Manager,
Union Light & Power Company,
25 East Central Street,
Franklin, Mass.

Thomas H. Bibber,
New England Manager,
Duplex Lighting Works of G. E. Co.,
6 W. 48th Street,
New York City.

John J. Gaffey,
Asst. to Engineering Mgr.,
Harry M. Hope Engineering Co.,
185 Devonshire Street,
Boston, Mass.

Ernest L. Munger,
Gen. Mgr., Gloucester Electric Co.,
26 Vincent Street,
Gloucester, Mass.

Albert F. Wakefield,
F. W. Wakefield Brass Co.,
Vermilion, Ohio.

Bowen Tufts,
Banker,
C. D. Parker & Co., Inc.,
78 Devonshire Street,
Boston, Mass.

Galt Fayette Parsons,
Consulting Engineer,
Perry & Parsons, Engineers,
78 Devonshire Street,
Boston, Mass.

Harry Swindell,
Salesman,
Ivanhoe Regent Works of Gen. Elec. Co.,
5716 Euclid Ave.,
Cleveland, Ohio.

Eighteen Associate Members.

J. LEE POTTER,
Gen. Mgr. Newburyport Gas & Elec. Co.,
57 Pleasant Street,
Newburyport, Mass.

EDWARD YOUNG DAVIDSON, JR.,
Illuminating Engineer,
Macbeth Evans Glass Company,
157 North Craig Street,
Pittsburgh, Pa.

THOMAS A. LEES,
Manager, Manchester Electric Co.,
21 Summer Street,
Manchester, Mass.

ALEXANDER MACAULAY,
Supt. Beverly Gas & Elec. Co.,
Beverly, Mass.

F. H. SMITH,
Asst. Gen. Mgr.,
11 Foster Street,
Worcester, Mass.

FRED E. WATERMAN,
Treasurer and Manager,
Waterman Supply Co., Inc.,
79 Purchase Street,
Fall River, Mass.

WILLIAM D. MACGUFFIN,
Salesman, Edison Lamp Works,
84 State Street,
Boston, Mass.

L. W. DAVIS,
Branch Mgr. Westinghouse Lamp Co.,
801 Van Nuys Bldg.,
Los Angeles, Cal.

CLARK BAKER,
Asst. to Mgr. for Pacific Coast,
National Mazda Lamp Div. of Gen. Elec. Co.,
1648 16th Street,
Oakland, Cal.

BERNHARD P. LEINWEBER,
Sales Engineer, Central Elec. Co.,
316 South Wells Street,
Chicago, Ill.

FRANK N. SANDERSON,
Manager, The Electric Lt. & Power Co., of Abingdon and Rockland,
64 Charles Street,
North Abington, Mass.

GEORGE OSCAR HODGSON,
District Sales Manager,
Edison Lamp Works of G. E. Co.,
First National Bank Bldg.,
Denver, Colo.

HUGH S. RIDDELL,
Commercial Manager,
Greenfield Electric & Power Co.,
39-41 Federal Street,
Greenfield, Mass.

WALTER R. TIMPER,
Manager Edison Lamp Dept.,
Pettengell-Andrews Company,
160 Pearl Street,
Boston, Mass.

P. B. ZIMMERMAN,
Advertising Manager,
National Lamp Works of G. E. Co.,
Nela Park,
Cleveland, Ohio.

MANLIO A. SMILARI,
946 East 181st Street,
New York City.

FRANK L. QUINN,
Engineering Dept.,
Lord Electric Co.,
105 West 40th Street,
New York City.

FREDERICK C. WYSS,
Designing Engineer,
Lord Electric Co.,
105 W. 40th Street,
New York City.

Five Transfers.

EDWARD H. HOBBIE,
Publicity and Promotion Manager,
Mississippi Glass Company,
220 Fifth Avenue,
New York City.

EARL A. ANDERSON,
Illuminating Engineering Dept.,
National Lamp Works of Gen. Elec. Co.,
Nela Park,
Cleveland, Ohio.

MAX POSER,
Special Representative,
Bausch & Lomb Optical Co.,
St. Paul Street,
Rochester, N. Y.

FRANK SHREVE PRICE,
President,
Pettengell-Andrews Co.,
160 Pearl Street,
Boston, Mass.

OLIN JEROME FERGUSON,
Professor of Electrical Engineering,
University of Nebraska,
Station A,
Lincoln, Neb.

OTHER CHANGES IN MEMBERSHIP.—

One Associate Member Resigned.

P. S. KLEES,
Formerly Sales Manager,
The Franklin Electric Mfg. Co.,
Hartford, Conn.
Now
Vice-President & General Manager,
Pierce Fuse Corporation,
Buffalo, N. Y.

One Associate Member Deceased.

NIZO ITO,
Tokyo Electric Company,
Kawasake-Machi,
Kanagawaken, Japan.

COMMITTEE ACTIVITY.

Special Committee on Handbook and Indexing.—The Council laid on the table consideration of a lighting handbook and will hold it pending with the intention of reconsidering it a year hence.

Complete Index of Transactions.—The Committee reported that in order to be properly discriminating, the index and cross index would either have to be prepared by a committee of members or it would have to be planned and supervised by a committee of members.

This report was accepted and the committee discharged. The Council requested the President to appoint a committee to allot the work on this index and to supervise its compilation.

Report of Committee on Lighting Legislation in Regard to a Code of Fixture Design, suggested that the Society prepare the technical specifications so far as the lighting features are concerned, but that the fixture manufacturers should be the ones to compile the code and that a committee be appointed to co-operate with the fixture manufacturers in establishing a code of Fixture Design.

Progress Report of Committee on Lighting Legislation.—Chairman L. B. Marks made a progress report of the Committee on Lighting Legislation in connection with the revision of the code.

Committee on Revision of Constitution and By-Laws reported that 148 signatures to the proposed amendments had been secured and that same were ready to be submitted to the membership.

Committee on Education.—The Council directed that the 1914 report of the Committee on Education be referred to the present Committee on Education for revision.

The Work of the Committee on Education.

The organization of this committee provides for several subcommittees to deal with different phases of its activities. In this way the work in the colleges, both as to formal courses in il-

lumination and as to special matter to be introduced into other courses for students in physics, mechanical engineering, domestic science, architecture, and other lines is taken care of by a sub-committee under Professor C. F. Scott of Yale University. An extension or correspondence course is being prepared by another sub-committee under Mr. F. A. Vaughn, Vice-President of the School of Engineering of Milwaukee. Mr. F. A. Grohsmeyer, Illuminating Engineer of the Northern Ohio Traction & Light Co., heads the sub-committee on popular education and is at present engaged in putting the finishing touches upon an illustrated lecture on industrial lighting. Another section of the committee will later be appointed to take up the work in connection with the secondary schools of the country.

Beside the chairmen of these various sub-committees, there is a group of "field members," whose duties take them over a considerable part of the country, and who besides giving the benefit of their experience and counsel to the committee form a means of direct communication with the educational centers. Messrs. W. M. Skiff of the Engineering Department at Nela Park and Mr. A. L. Powell of the Edison Lamp Works at Harrison, New Jersey, are the first to be selected for this group.

The committee held its second meeting for the year on April 5th, at the Ohio State University, at Columbus. Reports made by the Field Members, who had recently visited a number of educational institutions, indicated that while excellent work is being done at some colleges, in many cases little or nothing is being attempted. They also found that where courses in illumination are given the subject matter varies widely, and is often not up-to-date in dealing with the design of lighting systems. It was decided that one of the first duties of the committee would be to conduct a campaign to interest those men in the various colleges in whose fields of work, the study of illumination properly falls. To ascertain exactly the present status of education in illumination, and to bring the records of the Society up-to-date, a preliminary letter and questions will shortly be sent out to a list of instructors in electrical engineering and physics. Based upon the data so received, a mailing list will be constructed to which a series of letters or bulletins will be sent at frequent intervals. It is intended that as far as possible these men shall become centers for the further spread of the gospel of good lighting in their respective districts.

The committee has already obtained the promise of co-operation as "corresponding members" from about fifty members of the Society, chiefly college teachers. This list will be extended as other educators show their interest in the work. Volunteers are called for and will be much appreciated.

Mr. Vaughn, for the sub-committee on extension, submitted a tentative program of lessons or assignments and also a rough draft for the first of these. It is planned that at the June meeting of the Council the committee will be ready to submit a definite proposition with regard to the publication of this course. This is intended primarily for those in the industries, the character of whose work now makes them feel the need of elementary instruction along this line. It is not intended that the Society will itself conduct such courses, but that it will encourage schools and other organizations to do the work of instruction and supervision.

Another field in which the committee hopes to obtain good results is in co-operation with the Committee on Re-

search. It is proposed to suggest subjects which are especially suitable for investigation under the conditions found in colleges and to promote such research in any ways that may be found to be practicable.

Committee on Automobile Headlighting Specifications.

Invitation has been received from National Traffic Officers' Association to send a delegate to their Annual Convention, August 23rd to 27th, San Francisco, California. Dr. Sharp was appointed as the official representative of the Society.

Industrial Lighting State Codes.

The Council decided that copies of all the State Codes which have been published be bound in suitable cover and issued to those who make request for Lighting Codes, at a price to cover expense of binding.

The question of preparing and publishing a series of Monographs or Symposiums of Lighting, made up of extracts from TRANSACTIONS codified according to topic and brought up-to-date was offered for consideration and the Council requested that the President, General Secretary and Assistant Secretary formulate a plan and report further to the Council.

Local Representative, Buffalo, N. Y.

The resignation of Dr. F. Park Lewis, Ophthalmologist, 454 Franklin Street, Buffalo, N. Y., as local representative has been accepted.

NEWS ITEMS.

GENERAL OFFICERS NOMINATED FOR 1920-21.

President—Genl. Geo. H. Harries
General Secretary—Clarence L. Law
Treasurer—L. B. Marks
Vice-Presidents—
H. F. Wallace
Dr. Geo. S. Crampton
J. J. Kirk
Directors—
Adolph Hertz
Walton Forstall
Frank S. Price

Factory Lighting.

The *New York Sunday Times,* April 4th, Editorial Section gives column and half of publicity to an article on "Factory Lighting" by State Factory Inspector George C. Ward, which was published in the monthly bulletin of the New York State Industrial Commission. Mr. Ward's article has considerable historical interest as well as present day application. Among the important points emphasized is the avoidance of glare and glaring lights and urges industrial plants to make a practice of retaining the services of a competent illuminating engineer. Mention is also made of the I. E. S. Industrial Lighting Code.

Illumination in Relation to Industrial Output to be Discussed by Taylor Society.

Ward Harrison, Chairman Committee on Reciprocal Relations, is scheduled to present a paper before the Taylor Society at its meeting in Rochester, N. Y., May 7th. The subject of the paper will be, "The Necessity of Standards of the Relation Between Illumination and Output."

The Canadian Gas Association 13th Annual Convention.

To be held at Ottawa, Canada, Friday and Saturday, August 27th and 28th, 1920. Hotel reservations can be arranged through the Secretary, G. W. Allen, 19 Toronto Street, Toronto, Ontario, Canada, who will also supply full information on application.

British Illuminating Engineers Hear Discussion on Important Topics.

By courtesy of the Royal Society of Arts, members of the British Illuminating Engineering Society were invited to be present at the presentation of a paper by Mr. L. Gaster, entitled "Industrial Lighting in Relation to Efficiency," and at their own meeting on March 30th, the subject, "Motor Car Headlights in Relation to Traffic Problems."

Personal Mention.

Robert M. Searle, vice-president of the Rochester (N. Y.) Railway & Light Company, has been elected president of that company to succeed James T. Hutchings, who has resigned to become assistant general manager of the United Gas Improvement Company of Philadelphia. Mr. Searle went to Rochester fourteen years ago.

Old Copies Wanted.

Wanted—a few copies of the following issues of "TRANSACTIONS."

General Office will pay fifty cents ($0.50) per copy.

Volume One—
- No. 1
- No. 2
- No. 3
- No. 8
- No. 9

Volume Two—
- No. 1
- No. 3
- No. 4

Volume Three—
- No. 1
- No. 2
- No. 4

Volume Eight—
- No. 7
- No. 8
- No. 9

Volume Nine—
- No. 2

Volume Ten—
- No. 8

BOOKS.

Airplane Photography.—Herbert E. Ives, published by the J. B. Lippincott Co., Philadelphia, 1920. 413 pages with index and 208 illustrations.

The author who was a Major in charge of Experimental Department, Photographic Branch of the Air Service during the war, has compiled the results of his observations and experience in this book on the practice and application of aerial photography. He discusses the airplane camera; its suspension and installation; sensitized materials and chemicals; methods of handling plates, films and papers; practical problems and data; and the future of aerial photography including technical and pictorial uses, exploration and mapping. A chapter of especial interest to members of this Society deals with the distribution of light, shade and color in the aerial view.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV JUNE 10, 1920 No. 4

SECTION ACTIVITIES.

CHICAGO.

Meeting—May, 1920.

The May meeting of the Chicago Section, the last of the present series of meetings, was held at the Lewis Institute on Thursday evening, May 13th, at 8 P. M. The speaker of the evening was Prof. F. C. Caldwell, who delivered a very interesting lecture on "Good Lighting in Schools."

Special Meeting—Milwaukee.

On May 14, 1920, in cooperation with the Chicago Section I. E. S., a special meeting was held in an assembly room of the School of Engineering of Milwaukee, at which Prof. F. C. Caldwell, Director, Department of Electrical Engineering, Ohio State University, Chairman, Committee on Education, I. E. S., read a paper upon the subject of "Good Lighting in Schools."

The Society's local representative, F. A. Vaughn, acting as chairman, led the discussion, which was participated in by F. H. Bernhard, Chairman, Chicago Section, I. E. S., Mr. John A. Hoeveler, illuminating engineer for the Wisconsin Industrial Commission, Mr. John Callahan, of the State Board for Vocational Education, and F. A. Kartak, of the School of Engineering of Milwaukee.

Invitations were sent out by the local representative to the State Superintendent of Public Instruction, the State Board for Vocational Education, the State Board of Education, the Industrial Commission, the Board of Education of Milwaukee, the Schoolmasters' Club, the Milwaukee Principals' Association, the Milwaukee Teachers' Association, the Milwaukee High School Teachers' Association, the Milwaukee Kindergarten Association, and other educational associations in the city and state. The audience that night was largely composed of representatives and teachers from the various schools and colleges.

Professor Caldwell's paper brought home to this audience the vital necessity of some protective action against the menace of poor lighting in our schools. The discussion, as well as the remarks during the inspection of the typical schoolroom laboratory lighting installation in the School of Engineering of Milwaukee, indicated that Professor Caldwell impressed these men and women with the importance of the subject.

Since this meeting, a movement has been set in action to induce the Industrial Commission of Wisconsin to adopt and operate a code of school lighting such as that proposed by the I. E. S.

NEW YORK.

Meeting—May, 1920.

The May meeting of the New York Section was held Thursday evening, May 13th, at 8 o'clock at the Engineering Society Building, New York City.

It was preceded by an informal dinner at Healy's Restaurant.

The paper of the evening was by Mr. R. W. Shenton, of the National Electric Lamp Works, Cleveland, Ohio, and was entitled "Illuminating Engineering from the Sidelines." Mr. Shenton's paper was received with unusual interest. There was considerable discussion.

Meeting—June, 1920.

The June meeting of the New York Section will be held at the International Cinema-Quipment Center, 7th Avenue and 49th Street at 8.15 P. M. on June 17th. It will be Ladies' Night and the meeting will be preceded by a dinner.

The speaker of the evening will be E. L. Bragdon, Technical Editor of the *Motion Picture News,* whose subject will be "Where the Motion Picture and the Illuminating Engineer Meet." This will be followed by a demonstration by the Pathescope Company of America, showing their portable projector using the safety standard film. There will also be a talk by the representative of Prizma, Inc., which will be illustrated by a "reel" entitled "How Prizma Pictures are Made."

PHILADELPHIA.

Meeting—May, 1920.

The monthly meeting of the Philadelphia Section was held on Thursday evening, May 21st, at 8 o'clock at the Engineers Club. It was a Ladies' Night and the meeting was preceded by a dinner at the Club.

The first paper was by Mr. Henry Hess on "Color Photography" especially in connection with motion pictures. Mr. Hess gave a very able presentation of his subject, outlining the history of the work which has resulted in the present wonderful effects which are being attained in colored photography, describing the principles on which successful results depend, and illustrating many of his remarks with lantern slides, the talk closed with an exhibition of some motion pictures, taken on the most recently developed color recording film. Those present were intensely interested.

The second paper was the final of a very interesting series of talks by Dr. Howard Lyon on "The Elementary Principles of Illumination," discussing particularly, light, its character and properties.

Meeting—June, 1920.

The monthly meeting was held jointly with the Philadelphia Section, American Institute of Electrical Engineers, on June 7, 1920, at the Howard McCall Field, the athletic grounds of the Philadelphia Electric Company. The festivities were started in the afternoon with golf and baseball, followed at 7:00 P. M. by a dinner attended by 116 persons, at 8:00 P. M. by a short business meeting, and terminated with music and dancing. This outing was a very enjoyable occasion.

COUNCIL NOTES.

ITEMS OF INTEREST.

Upon the recommendation of the Board of Examiners, the following were elected to membership in the Society:-

Nine Members.

WILLIAM J. DRISKO,
Associate Professor of Physics,
Mass. Institute of Technology,
Cambridge, Mass.

HERBERT S. POTTER,
Electrical Engineering and Contracting,
240 State Street,
Boston, Mass.

RICHARD M. BEARD,
Proprietor, Americolite Co.,
101 Park Avenue,
New York, N. Y.

RALPH J. PATTERSON,
General Commercial Manager,
Twin State Gas & Elec. Co.,
55 Congress Street,
Boston, Mass.

FRANK E. WALLIS,
Architect,
56 West 45th Street,
New York, N. Y.

EUGENE H. MATHEWS,
Illuminating Engineer,
American Ever Ready Works of National Carbon Co.,
Thompson Ave. and Orton St.,
Long Island City, N. Y.

JESSE M. COAHRAN,
Electrical Engineer,
University of New Mexico,
Albuquerque, N. M.

LYMAN DAY MORGAN,
Specialist in Charge of Lighting,
Western Electric Co.,
94 Marion Street,
Seattle, Wash.

A. JACKSON MARSHALL,
Committee Secretary,
National Electric Light Asso.,
29 West 39th Street,
New York N. Y.

Twenty-three Associate Members.

ARTHUR W. MARCOU,
General Manager,
Bryan-Marsh Division of Gen. Elec. Co.,
521 Mill Street,
Central Falls, R. I.

N. R. STANSEL,
Local Manager,
Southwest General Electric Co.,
206-8 San Francisco St.,
El Paso, Tex.

F. E. KOPECKY,
Southern Representative,
Shelby Lamp Division, National Lamp Works of G. E. Co.,
1502 Healey Bldg.,
Atlanta, Ga.

CHARLES C. COLBY, JR.,
B. F. Goodrich Co.,
Akron, Ohio.

OSCAR H. PERKINS,
Sales Manager,
Stuart Howland Co.,
234 Congress Street,
Boston, Mass.

BEN L. COTES,
Salesman,
Lewis Electrical Supply Co.,
117 Federal Street,
Boston, Mass.

C. EDWARD FEE,
Eastern Manager,
Sunbeam Division, National Lamp Works of General Electric Co.,
151 Fifth Avenue,
New York, N. Y.

ALFRED J. NATHO,
Service Engineer,
Indianapolis Electric Supply Co.,
122 S. Meridian Street,
Indianapolis, Ind.

HAROLD D. LESLIE,
Manager Industrial Maintenance Sales,
Sherwin-Williams Co.,
Brown St. and Lister Ave.,
Newark, N. J.

HUGO EISENMENGER,
Consulting Engineer,
655 Tonti Street,
La Salle, Ill.

ASHTON E. WARNER,
Manager New Business Dept.,
Dallas Power & Light Co.,
217 Interurban Bldg.,
Dallas, Tex.

JOSEPH E. BAIN,
Mgr. Fixture & Illuminating Dept.,
Southwest General Electric Co.,
R-521 Interurban Bldg.,
Dallas, Tex.

HENRY ELMER HOBSON,
Sales Manager,
Southwest General Electric Co.,
Interurban Bldg.,
Dallas, Tex.

HOMER D. PUCKETT,
Mgr. Lamp Sales Dept.,
Southwest General Electric Co.,
R-518 Interurban Bldg.,
Dallas, Tex.

GUY D. MARMON,
Mgr. Appliance Sales,
Texas Power & Light Co.,
619 Interurban Bldg.,
Dallas, Tex.

C. ROBERT CHURCHILL,
President and Gen. Mgr.,
Electric Appliance Co.,
408 Canal Street,
New Orleans, La.

W. T. WESSELS,
Power and Lighting Specialist,
J. F. Buchanan Supply Co.,
1719 Chestnut St.,
Philadelphia, Pa.

WILLIAM A. PORTERFIELD,
Mgr. Street Lighting Dept.,
Southwest Gen. Elec. Co.,
R-506 Interurban Bldg.,
Dallas, Tex.

EDWIN J. WOOD,
Charge of Lighting Salesmen,
Narragansett Elec. Lighting Co.,
814 Turks Head Bldg.,
Providence, R. I.

CLARENCE F. GRISWOLD,
Lighting Salesman,
Narragansett Elec. Lighting Co.,
814 Turks Head Bldg.,
Providence, R. I.

THOMAS J. TOOHEY,
Lighting Salesman,
Narragansett Elec. Lighting Co.,
814 Turks Head Bldg.,
Providence, R. I.

WILLIAM W. O'DONNELL,
Lighting Salesman,
Narragansett Elec. Lighting Co.,
Arctic, R. I.

FLOYD W. HOWE,
Lighting Salesman,
Narragansett Elec. Lighting Co.,
814 Turks Head Bldg.,
Providence, R. I.

Five Transfers to Grade of Member.

EMILE G. PERROT,
Architect and Engineer,
Ballinger & Perrot,
N. W. Cor. 17th and Arch Sts.,
Philadelphia, Pa.

M. BERNARD WEBBER,
Assistant Manager,
Athol Gas & Electric Co.,
78 Devonshire Street,
Boston, Mass.

E. CANTELO WHITE,
Manager, General Lighting Dept.,
Western Electric Co.,
195 Broadway,
New York, N. Y.

FRANK D. PEMBLETON,
Asst. to New Business Agent,
Public Service Electric Co.,
80 Park Place,
Newark, N. J.

ADOLPHE ALFRED DION,
Gen. Supt., Chief Engineer and Director,
The Ottawa Electric Co.,
The Ottawa Gas Co.,
35 Sparks Street,
Ottawa, Ontario, Canada.

Resignations.

HARVEY J. HOWARD (Member)
Medical Research Laboratory,
Hazlehurst Field,
Mineola, L. I.

W. K. HARRINGTON (Associate Member)
American Meter Co.,
11th Avenue and 47th Street,
New York, N. Y.

COMMITTEE ACTIVITIES.

Committee on Lighting Legislation.—Mr. Marks, as Chairman, reported at the May Council meeting that the Committee was proceeding with the revision of the Industrial Lighting Code, without the cooperation of the American Engineering Standards Committee, but that the question of submitting this revised Code to the American Engineering Standards Committee for approval as a tentative American Standard, had once more been brought up by Dr. Rosa, Chairman, National Safety Code Committee.

It was decided that the Chairman of the Committee on Lighting Legislation be authorized to act for the Society in the matter of carrying out the revision and issuance of the Industrial Lighting Code, under the method of procedure of the American Engineering Standards Committee.

Mr. Marks also gave a Progress Report of the Massachusetts Code and the Ohio Code.

Committee on Time and Place.—Report was read from Mr. Serrill, Chairman of Committee on Time and Place, recommending that the 1920 Convention be held in Cleveland, some time in September.

Report was accepted and the Committee discharged.

It was voted that the date of the Convention be the last four days in September, subject to the approval of the Convention Committee.

Committee on Publicity.—The Committee on Publicity, at the President's request, considered the publications of the Society, and made the following recommendations at the May Council meeting:

First, that a monthly publication be issued, to be known as a JOURNAL (6 x 9) to contain from 16 to 24 pages and that the TRANSACTIONS (or what is now known as Part II) be issued annually in the form of a bound volume.

Second, that standing reports of technical committees be examined by their respective committees each year and have revision if deemed necessary, the same to be reprinted after revisions.

Third, that the Society arrange for a series of monographs or symposiums, one each, for the various important topics in the illuminating field and that these symposiums be examined annually for revision.

Fourth, that this report is offered without consideration as to the matter of finance.

The report was accepted and motion made and carried that the Committee on Finance and Committee on Papers should consider this report in detail and recommend to the Council what the procedure should be in order to carry out this plan.

Membership Drive Planning Committee.—Mr. Law gave an outline drawn up by the Committee. It was decided at the May meeting of the Council that a Membership Drive be undertaken, that the Executive Committee manage the Drive, also a committee be appointed to carry on the Drive (the latter to be composed of leaders in each business or professional group interested in lighting), that the sum of $750 be appropriated for this purpose and that the date of the Intensive Drive be left to the Membership Drive Committee.

Committee on Reciprocal Relations.—A Progress Report of the Committee on Reciprocal Relations was presented at the May meeting of the Council.

Following the outline proposed, the Committee has considered several methods of reaching the more important industrial plants through the various engineering, industrial and commercial associations, throughout the country.

Our present plan is to approach the officials of these organizations with whom educational and standardization work on lighting practice is contemplated, with a view to the presentation of a paper on Modern Lighting, at their annual convention.

The Committee has compiled information as to the time and place of the annual convention and the active officials of a number of these different organizations, as follows:

In order to obtain the maximum effectiveness from the lecture on Lighting, an especial effort will be made to secure the cooperation of the local central station to have simultaneously an industrial lighting demonstration similar to the one to be presented at the 1920 N. E. L. A. Convention at Pasadena.

To assist in carrying on the active details of this work, arrangements have been made with the Ivanhoe-Regent Works of General Electric Company for the temporary services of Mr. Harry Swindell, who will act as a representative of the Committee in planning with the Secretaries of the various associations the space on the program and the procurement of speakers on the subject of Lighting.

NAME	PLACE	DATE	PROBABLE ATTENDANCE
Amer. Inst. of Elec. Engnrs.	White Sulphur Spr., W. Va.	June 29 to July 2, 1920	400
Amer. Specialty Mfgrs. Assn.	Atlantic City	Nov. 20-21, 1920	300
Amer. Institute of Metals	Philadelphia	Sept. 29, 1920	200
Assn. Iron & Steel El. Engrs.	New York City	Sept., 1920	500
Ill. Elec. Contr. Assn.	Chicago	Oct. 17-18, 1920	200
Int. Stamp Mfgrs. Assn.	Philadelphia	June, 1920	200
Iowa Elec. Light Assn.	Des Moines	June, 1920	150
Middle States Textile Mfgrs. Assn.	Louisville	July, 1920	
Nat. Assn. Brass Mfgrs.	New York	Dec., 1920	100
Nat. Assn. Bldg. Owners & Mgrs.	Minneapolis	June 23-29, 1920	250
Nat. Assn. Industrial Accident Boards of Commis.	San Francisco	Sept., 1920	
Nat. Assn. Leather Glove Mfgrs.	Chicago	June 1, 1920	
Nat. Expo. of Chemical Industries	New York	Sept. 20-25, 1920	
Nat. Harness Mfgrs. Assn.	Detroit	1920	500
Nat. Assn. Stationers & Mfgrs.	St. Louis	Oct., 1920	400
Nat. Tent & Awning Mfgrs. Assn.	San Francisco	Sept. 23-30, 1920	400
No. Georgia Cotton Buyers & Mfgrs.	Atlanta	Aug., 1920	
North West Section Nat. El. Lt & Power Assn.	Spokane	Sept., 1920	300
Ohio Elec. Light Assn.	Cedar Point	July 13-16, 1920	500
Paint Mfgrs. Assn. of U. S.	New York	Oct. or Nov., 1920	100
Ry. Elec. Supply Mfgrs. Assn.	Chicago	Oct. or Nov., 1920	400
Ry. Equipment Mfgrs. Assn.	Chicago,	Sept., 1920	1,000
The Ry. Supply Mfgrs. Assn.	Atlantic City	June 9-16, 1920	5,000
State Mfgrs. Assn.	Burlington	1920	300

Plans are in effect for obtaining the same information in regard to the remainder of the selected list of associations.

Respectfully submitted,

WARD HARRISON,
Chairman.

CONFIRMATION OF APPOINTMENTS.

It was voted at the May meeting of the Council that the following appointments by the President be confirmed:

Prof. J. M. Coahran, State University of New Mexico, as Local Representative in Albuquerque, New Mexico.

H. G. Hake, Washington University, St. Louis, as Delegate to the Fifth Annual Convention of American Association of Engineers at St. Louis, May 10th and 11th.

NEW COMMITTEE APPOINTMENTS.

The following appointments by the President were confirmed:

Committee on Editing and Publication.

Dr. A. S. McAllister
G. H. Stickney
P. S. Millar

and the Committee is to select its chairman.

Committee on Papers.—A new Committee on Papers was appointed as follows:

G. H. Stickney, Chairman

Program Group

P. S. Millar, Vice-Chairman
C. E. Clewell
A. H. Meyer
E. A. Anderson
E. B. Rosa
F. V. Westermaier
F. H. Murphy

Approval Group

L. J. Lewinson
A. S. McAllister
C. O. Bond
J. D. Israel

Convention Committee.—

Robert Lindsay, Chairman
W. M. Skiff, Vice-Chairman
H. K. Morrison
H. A. Hornor
Otis L. Johnson
William J. Clark
Adolph Hertz
Clarence L. Law
Preston S. Millar

The Committee to be added to as suggested by the Chairman.

Committee to Cooperate with Fixture Manufacturers.—

(To assist the Association of Fixture Manufacturers in preparing a Code of Fixture Design)

M. Luckiesh, Chairman
Bassett Jones
S. G. Hibben
A. L. Powell
W. T. Blackwell
R. H. Maurer

Committee to Supervise and Allot Work on Proposed Index and Cross Index to Transactions.—This matter was held up pending the report of the Committees on Papers and Finance on the Publicity Committee's recommendations.

Committee on Revision of Constitution and By-Laws.—The resignation of Mr. Stickney as Chairman of the Committee on Revision of Constitution and By-Laws was accepted and the Council extended its thanks to Mr. Stickney for his services.

The appointment by the President of Mr. Serrill, as Chairman in Mr. Stickney's place, was confirmed.

Tellers Committee.—

S. W. Van Rensselaer, Chairman
R. E. Harrington
R. H. Maurer
A. C. Dick
E. F. Dibelius

NEWS ITEMS.

1920 I. E. S. CONVENTION.

Make your plans for the month of September, so that you can spend the last four days of that month attending the I. E. S. Convention at Cleveland, Ohio.

THE SHERINGHAM DAYLIGHT REFLECTOR.

By L. C. Martin.

Reprinted from the Illuminating Engineer, London.

The Sheringham device makes use of a colored reflector for correcting the distribution of energy in the spectrum of the artificial source. It was originally founded on the invention of Mr. G. Sheringham, the well-known artist, who used simple colored reflectors or shades with artificial sources and found the quality of the light for painting immensely improved. The possibilities of the system have been to some extent worked out by the present exhibitor, the requisite distribution of colors being calculated on spectro-photometric measurements on opaque pigments made by means of Abney's color-patch apparatus. It is necessary in general to make use of arrangements to reflect the whole of the light from the colored surface, thus producing a type of indirect lighting unit which should have great possibilities in connection with shop window lighting and many other commercial and industrial uses. Approximate calculations indicate that the luminous efficiency obtainable is roughly the same as that of the transmission units which give an equivalent correction. Sunlight units of much higher luminous efficiency can easily be arranged by introducing white areas into the reflector.

INDUSTRIAL LIGHTING.

Engineering Department, National Lamp Works.

The Engineering Department of the National Lamp Works of the General Electric Co. have recently distributed a very interesting brochure on modern lighting with examples of its successful application in the industries. There are twenty 6 x 9 plates with interleaved data sheets showing the specifications for each installation pictured.

INDUSTRIAL LIGHTING CODES.

Chairman L. B. Marks of the Lighting Legislation Committee, sent in for publication the very interesting letter quoted below.

BUREAU OF ELECTRICAL AND MECHANICAL EQUIPMENT OF LABOR, STATE OF NEW JERSEY.

April 1, 1920.

To Secretary, Manufacturers Association of New Jersey.

SIR:

Following the suggestion that you would be interested in the subject of the Code of Lighting issued by this Department, and asking for some data concerning its preparation and application, I take pleasure in enclosing a copy of papers read at the last Convention of the Illuminating Engineering Society.

The necessity of good lighting in our industries is clearly set forth in these papers, since it is shown that the accident ratio bears a direct relationship to the lighting problem. Not only is this so, but it can be clearly shown where data is collected that the increase in production under proper lighting conditions is very marked. Speaking on this phase of the matter the writer had occasion to personally pass upon a new system of lighting installed in one of the prominent plants in the hatting industry and my observations and inquiries led me to believe that there will be approximately a 20% increase in production and that there will be a reduc-

tion of approximately 66% in spoilage. Good lighting bears a particularly definite relationship to rejected materials in these industries. These matters are entirely aside from the comfort of the worker, a phase of the problem which is also adequately dealt with in the rule pertaining to proper shading of all light sources in order to reduce or eliminate eye strain.

It is understood that you are also interested in the manner in which this Code was conceived, prepared and acted upon. In this connection we call attention to the cooperation offered by the Illuminating Engineering Society. This society appointed what they were pleased to term a Legislative Committee.

This Committee made a study of the peculiar conditions confronting the bodies supervising industrial plants in the several eastern states and with the cooperation of some of these bodies shaped a draft of a Code which is practically the same in all particulars as the Code now effective in this State. This work was then submitted to the States of New York, New Jersey and Pennsylvania for such action as seemed desirable, and with the cooperation of the engineering branches of the three Labor Departments a draft of the Code was whipped into final shape and accepted and placed in effect by Pennsylvania and New Jersey. Following closely on this action New York adopted a similar code and the State of Wisconsin followed suit.

This Code represents the best practice in the lighting field and the Illuminating Engineering Society stands ready to render similar assistance to any state or organization desiring similar help.

(Signed) R. H. Leveridge,
Chief.

OREGON STATE CODE.

The general office has received copies of the new Industrial Lighting Code from Mr. C. H. Gram, Commissioner, Bureau of Labor, State of Oregon.

This Code follows very closely the standards advocated by our Society.

A preface by the Lighting Commission is reprinted below:

PREFACE.

In the future, even more than in the past, the need of conserving the human element will be necessary. There are many reasons for this condition, such as the restricted supply of labor, high wages, high cost of material and keen competition in the world market. All of these will appeal to the employer directly and will cause him to take steps himself to protect the laborer in his plant. Of even greater importance, however, is the humanitarian side, the saving of human lives, the prevention of human wrecks and the improvement in human comfort and contentment; but because these factors do not seem to be so directly connected with the cost of production the average employer gives less attention to them, although in the end he pays a high price for this neglect. However, the fruit of this negligence does not fall alone upon the employer but the state must bear a large proportion of this cost directly in the form of pensions, compensation, and the maintenance of institutions for cripples and other dependents; and indirectly in the loss of the productive, and the increase of the dependent element of its production.

This state has endeavored in the past to improve conditions by establishing a Bureau of Labor with its corps of inspectors as well as an Industrial Accident Commission. It has been shown by careful investigation in recent years that not less than 20 per cent. of the preventable accidents are due, either directly or indirectly, to improper illumination. The 1919 legislature of the state of Oregon therefore took one more important step toward the prevention of unnecessary accidents by providing for proper general and emergency lighting, both natural and artificial, in all places of employment.

In presenting this bulletin to the public, acknowledgment is due to the Illuminating Engineering Society for the work it has done in pioneering the way for industrial lighting codes and to certain of its members individually for very material help in assisting the state of Oregon to secure suitable legislation along this line, especially is this true of the assistance rendered by Mr. L. B.

Marks, chairman of the Divisional Lighting Committee, a subdivision of the Advisory Council of National Defense.

Particular reference is made to the Code of Lighting—Factories, Mills and Other Work Places—prepared by the Industrial Lighting Code Committee and published in 1915. Much of the subject matter of this bulletin has been taken from that code and used verbatim, such additional notes and rearrangements being made as were deemed more suitable to local conditions. Credit is also due to the industrial commissions of New York, New Jersey, Pennsylvania, Ohio, Wisconsin and California and to the engineering department of the National Lamp Works of the General Electric Company for helpful suggestions obtained from their lighting bulletins, as well as to the Edison Lamp Works, the National Lamp Works and the Ivanhoe-Regent Works of the General Electric Company; the X-Ray Reflector Company, the Holophane Glass Company, the Wisconsin Industrial Commission, and the Illuminating Engineering Society for many illustrations used in this bulletin.

In accordance with Section 8, Chapter 181, General Laws of Oregon, 1919, the Commissioner of Labor of the state of Oregon appointed a Lighting Commission consisting of three persons. This commission, after holding many meetings and with the active and valuable assistance of the Commissioner of Labor, presents herewith its report in the form of a lighting bulletin, embracing the legislative act, together with the lighting rules determined by the commission and their explanatory notes forming an appendix to these rules.

LIGHTING COMMISSION
V. H. HAYBARKER,
F. C. KNAPP, *Chairman,*
F. H. MURPHY, *Secretary.*

OHIO STATE CODE.

This Code has just been adopted by the Industrial Commission of Ohio as a "guide for inspection" to be used by the factory inspectors of the commission in issuing orders for the improvement of industrial lighting systems.

It is expected that the code will be used in this way for about a year, before it is given the force of a general law. During this period an educational campaign will be carried on by the Safety Department of the Commission.

This Code is based on the I. E. S. Code, which it follows quite closely in most of its provisions. It differs from the latter chiefly in having an additional grade of ½ foot-candle minimum for very rough work, and in the omission of the rules for emergency lighting and controlling apparatus. There are also several notes intended to make the rules more specific. The Appendix is entirely different; its most notable feature is a list of industrial operations with recommended foot-candles.

The Code was drawn up by a committee of eight, among whom were the following members of the Society: President S. E. Doane, J. Q. Adams, Architect of the Industrial Commission, H. L. Jenkins, of the Holophane Glass Co., Geo. W. Walker of the Cooper-Hewitt Elec. Co., and F. C. Caldwell of the Ohio State University, Chairman.

With the exception of opposition from a single important industry, practically no objection has been made to the Code in its present form. Nine public hearings of one day each were held in six different cities.

Work on the Code was commenced in June, 1917, but on account of the thorough way in which safety codes are constructed in Ohio the final action adopting the Code has just been taken by the Commission.

INTERNATIONAL COMMISSION ON ILLUMINATION.

Report of the President of the U. S. National Committee for the Year 1918-1919.

[The Illuminating Engineering Society is represented on the U. S. National Committee of International Commission on Illumination by Messrs. Louis Bell, J. R. Cravath and P. S. Millar.]

In accordance with the statutes of the Committee, I beg to submit the following report for the fiscal year 1918-1919.

At the last annual meeting of the United States National Committee, the armistice had just been signed and there had, at that time, been no opportunity for international action looking to the re-establishment of the International Commission on Illumination.

In February of this year a letter was received from Mr. C. C. Paterson, Honorary Secretary of the Commission, addressed to the members of the Executive Committee of the Commission, suggesting a plan of procedure for the reorganization of the Commission and requesting the views of the members of the Executive Committee.

In order that the opinions expressed by the United States representatives on the Executive Committee might be consistent, the one with the other, and expressive of the combined judgment of the members of the United States National Committee, a special meeting of the Committee was called in April and the communication from Mr. Paterson was laid before it. It is unnecessary to reproduce here this communication which is on file in the office of the Secretary of the Committee, but it may be of some value to state briefly the proposals for reorganization which the President and Honorary Secretary of the International Commission submitted for consideration. I quote these proposals from Mr. Paterson's letter of February 21, 1919.

(1) That a new International Commission on Illumination be established.

(2) That the statutes of the old Commission be adopted for the new Commission, with such minor amendments as may be necessary to meet the new conditions.

(3) That a National Committee from any of the countries at war with the Central Empires may have a share in the work of the Commission provided it conforms with the Statutes.

(4) That neutral countries may also associate themselves in the same way with the work of the Commission and that in the first instance Holland and Switzerland be invited to take part in it.

(5) That if either or both these neutral countries prefer to remain outside the Commission, the new Commission nevertheless be started as (1), (2) and (3) above. In the event of no neutral countries joining in the work, the membership of the Commission would be restricted to allied and associated countries, and such others as would be introduced by them into the Commission.

(6) That the first meeting of the new International Commission be held in Paris at a date to be settled in due course when the situation has become more normal.

The Committee, after due deliberation, passed a resolution endorsing the proposals submitted by Mr. Paterson and suggesting that Mr. W. H. Gartley, one of the United States representatives on the Executive Committee of the International Commission, prepare a reply to Mr. Paterson's letter, stating that all the United States members of the Executive Committee, supported by the combined judgment of the members of

the United States Committee, endorsed the proposals that had been submitted.

Subsequently, Mr. Paterson, after having received replies from members of the Executive Committee resident in other countries, forwarded a second communication, outlining in more detail two possible methods of procedure, one proposed by M. P. Janet of France and one suggested by Dr. Harold G. Colman of England.

The only point in question regarding the reorganization of the Commission concerned the admission of neutral countries. It was felt in France that the first meeting of the Commission for reorganization should have representatives only from the four allied countries, Great Britain, France, Italy and the United States, which already had National Committees, and that the question of the admission of neutrals should be considered at this reorganization meeting.

Dr. Colman, cognizant of this attitude of the French representatives, but desirous of conserving time and of making the first international meeting as full a one as possible, suggested that a reorganization of the Commission with the old officers and with the old statutes, except for such minor modifications as might be necessary, should be accomplished by letter ballot among the four allied countries. After this had been accomplished, he suggested that the question of admission of neutrals might then be submitted by letter ballot to the National Committees of the four allied countries so that in case such a ballot led to admission of certain neutral countries, the first international conference would be as full as possible and could proceed at once to the discussion of technical matters.

Consistent with the views expressed in the earlier communication, Mr. Gartley replied in favor of the proposals of Dr. Colman, but as yet, no further word has been received from the Honorary Secretary.

It would seem, in view of these delays, that it is scarcely to be hoped that a plenary meeting of the Commission, under any plan of reorganization, can be planned before the summer of 1921, as I understand it to be the judgment of this Committee that no international conference should be called until a technical program is ready for consideration.

In my last report to this Committee I outlined the various activities which had been suggested several years ago as suitable ones for presentation to the International Commission at its first technical session. On the basis of this report several resolutions were passed making provision for the preparation of reports of these various technical matters. I shall consider them in the order in which the resolutions were made.

(1) Several years ago the Executive Sub-Committee of the U. S. National Committee outlined various investigations which were submitted to a number of laboratories with a suggestion that it would be of value to secure further data on these subjects, which included the following:

1. Methods of heterochromatic photometry.
2. Light filters.
3. Cooperative standardization of filters.
4. Objective photometry.
5. Primary standards.
    - (*a*) Existing standards.
    - (*b*) Black body.
    - (*c*) Metal filament standards.
    - (*d*) Other proposals.

Not a little work has been done, and in most of these subjects sufficient data

are now available to justify a report, which after approval by this Committee, might be submitted to the International Commission at its first technical session.

At the last annual meeting of the U. S. Committee, a resolution was passed instructing the President to appoint a Sub-Committee, with himself as Chairman, to collate the results of these investigations and to prepare reports to be submitted to the National Committee. The President appointed on this Sub-Committee, Messrs. Bond, Crittenden and Sharp, and at a meeting of this Sub-Committee, one or two of the subjects listed above were allotted to each member of the Committee. Up to the present time these reports have not been completed.

On one subject only did the Committee feel that still further investigations were necessary, namely:—Visibility of Radiation by the Direct Comparison Method.

The Sub-Committee on Research was of the opinion that it would be very valuable if the investigation of this subject could be undertaken promptly by the United States Bureau of Standards, and a request to that effect was made to the Director of the Bureau. Unfortunately the reply from the Bureau contained little or no hope that this investigation could be undertaken in the near future.

Subsequently, with the approval of the Sub-Committee, the Chairman submitted the problem to the Engineering Division of the Research Council, as a fundamental investigation underlying illuminating engineering. This matter is at present under process of negotiation with the Chairman of the Engineering Division, and it is too soon to forecast the outcome.

There would seem, however, to be good reason to believe that rather comprehensive reports with recommendations on these various fundamental questions might be available for presentation before the International Commission on Illumination at its first technical session, whenever the session might be held.

(2) Several years ago the suggestion was made that this country should recommend to the Honorary Secretary that all lighting codes in existence in the various countries adhering to the Commission should be collected to the end that there should be a more widespread, intelligent effort to encourage the framing of lighting codes everywhere. This activity, like others of our National Committee, was temporarily abandoned during the war, and at the annual meeting of the National Committee last year, it was thought advisable that a Sub-Committee of the U. S. National Committee should be appointed to bring together, in collaboration with the chairman of the Committee on Lighting Legislation of the Illuminating Engineering Society, all codes available in this country, and to transmit them to other National Committees, with the thought that they might be of value in connection with the reconstruction of the devastated portions of Belgium, France and Italy.

Pursuant to the resolution, a Sub-Committee was appointed consisting of Mr. Millar as chairman and with Mr. Cravath as the other member, and I take pleasure in reporting that this Sub-Committee promptly and most efficiently prepared a bound volume, entitled "Better Industrial Lighting in America," and containing an accurate statement of the aims and achievements in this country in the way of codes on industrial

lighting, followed by an appendix containing a copy of the Illuminating Engineering Society's code and the adopted or proposed codes of a half dozen states, together with several other publications which it was thought would be of interest. A copy of this bound volume has, I understand, been submitted to the National Committee of each of the allied countries adhering to the Commission.

(3) A third resolution was passed to the effect that a Sub-Committee be appointed to collect information as to the size of lamp bulbs, and the designation of the same in this and other countries, with a view to securing international uniformity as to the method of designation. A Sub-Committee consisting of Dr. Kennelly, Chairman, and Drs. Bell and Mailloux was appointed, but as yet this committee has not submitted any report.

E. P. HYDE,
President.

PROFESSIONAL OPPORTUNITIES.

Illuminating Engineer to prepare correspondence course in Electric Lighting and also to correct papers. Teaching experience desirable, but the ability to explain in writing is essential. Must be located near New York City. Z-1235

Old Copies Wanted.

Wanted—a few copies of the following issues of "TRANSACTIONS."

General Office will pay fifty cents ($0.50) per copy.

Volume One—
No. 1
No. 2
No. 3
No. 8
No. 9
Volume Two—
No. 1
No. 3
No. 4
Volume Three—
No. 1
No. 2
No. 4
Volume Eight—
No. 7
No. 8
No. 9
Volume Nine—
No. 2

BOOKS.

"The Art of Illumination"—H. M. Levylier, of Buenos Aires, Associate Member of the I. E. S. Contains 250 pages, size 7 x 9.

The book, which is printed in Spanish, is divided into four parts: the first dealing with luminous radiation, covering a study of the eye itself, together with some physiological and pathological phenomena; the second part is devoted to photometry and includes nomenclature and standards, laws, calculations of luminous flux, photometric apparatus, heterochromatic photometry and the application of photometric laws; the third part deals with illuminants and covers sunlight, oil and gas illuminants and electric illumination; the fourth part is concerned with the practice of illumination, the laws of diffusion, properties of reflectors, distribution of light, and the application of a number of specific cases.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

Engineering Index			
Illumination for Line Work to be Done at Night (Telegraph & Telephone Age, Vol. 37, No. 21, Nov. 1, 1919, pp. 524-525)—	B. J. Schwendt	Jan.	22a
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Daylight Illumination in the Shops (Int. Mar. Eng., Vol. 25, No. 2, Feb., 1920, pp. 122-126)—		Apr.	28a
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BRIGADIER-GENERAL GEORGE H. HARRIES,
President-Elect of the Illuminating Engineering Society
for the Fiscal Year 1920-1921.

From photograph taken in Berlin, April 28, 1918, immediately after the presentation by Gen. Dupont of the insignia of Commandeur Legion d'Honneur. The ceremony took place in the gardens of the French Embassy and is unique historically because it occurred in the German Capital while the Allies and the Central Powers were still at war but restrained from active hostilities by the Armistice. There is no record of any similar presentation under such circumstances.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV | JULY 20, 1920 | NO. 5

BRIGADIER-GENERAL GEORGE H. HARRIES.

President-Elect of the Iluminating Engineering Society
1920–1921.

"General Harries is best known to the membership of the Illuminating Engineering Society through the prominent part he has taken as presiding officer of some of our important and delightful social functions. His happy presence has unquestionably helped build up the cordiality and good fellowship which has been so influential as the foundation of the Society's cooperative spirit.

The following sketch by former Lieutenant C. M. Gailmard, Jr., introduces our new President as the world knows him."

General George Herbert Harries, born in the town of Haverfordwest, South Wales, in 1860. His early schooling was completed in the place of his nativity after which he came with his father and family to settle in Canada, subsequently coming to the United States and here established his citizenship.

General Harries' early career in the United States Army covered a wide range of experiences; from service against the Indians in their uprisings to the siege of Santiago de Cuba and the Cuban Army of Occupation in 1898—at which time he held the rank of Colonel, First District of Columbia Infantry, U. S. V. His military career from its inception to the outbreak of the World War was marked by signal honors, bringing him finally to the rank of Major-General commanding the Military and Naval Militia of the District of Columbia in 1915, at which time he was retired at his own request, his civil pursuits demanding his entire attention.

Although General Harries is well remembered as having done fine work in the literary field on the staff of the Washington (D. C.) *Star* in his early twenties, his greatest work in the field of civil endeavor is as a public utility executive and a consulting

engineer—his real life-work. As early as 1895 we find him as President of the Metropolitan Railway Company of Washington, D. C., and later as Vice-President of Washington (D. C.) Railway and Electric Company and of its subsidiaries, until 1911, at which time he leagued himself with the widely known engineering concern of H. M. Byllesby and Company of Chicago, Illinois, as Vice-President, and for some years also as President of the Louisville (Kentucky) Gas and Electric Company. His connection with H. M. Byllesby & Co., continues to the present time.

At the entry of the United States into the gigantic European struggle in 1917 he was again mustered into Federal Service, as a Brigadier-General of the National Army and stationed at Camp Cody, Deming, N. Mex., in command of a Depot Brigade —his civilian duties cast entirely aside.

From the moment of his entry into the world-struggle General Harries bent his every nerve and effort to training troops—with the one object in view: "Get over there and into it." This object, however, was not accomplished until a year later, after he had relinquished his charge at Camp Cody, leaving a well trained organization there, and going to Camp Jackson, S. C., and Camp Stewart, Va., where he organized the 186th Infantry Brigade (colored) and took it overseas; landing in France in April, 1918.

General Harries had hardly settled himself comfortably in his dug-out, in the heart of things surrounding Verdun, when an order from the Commander-in-Chief relieved him from duty with his brigade and sent him, with all speed, to command Base Section No. 5 with headquarters at the Port of Brest. This, because of his known genius as an organizer and an engineer. Anyone who is a "fighting-man" will understand and appreciate the General's feelings at being taken from what he had strived for with such heart-whole faith and industry.

A good soldier obeys, however, and the General is next seen with his every energy bent on landing troops, troop impediment and supplies of every nature at the very maximum speed and capacity-limit—with nothing in the way of assistance from outside sources such as machinery, lumber, etc., save the knowledge of his willing workers that he was toiling at top speed and wanted every man to see his own duty the same way. Such was

the General's genius as an organizer and builder that these workers actually "saw" his way and gloried in the seeing and the power to accomplish thereby for him. There is no place here for details—but when one considers that over 1,000,000 of the 2,000,000 men in France were landed, bag and baggage, and shipped to the front or distributing points in little more than six months; that huge camps and hospitals grew into being over night; that water in great quantity was obtained where the French geologists declared there was no water; that thousands of tons of freight were handled every day and every night, together with many other vast constructive enterprises at a port whose maximum receptive capacity had been estimated at 6,000 tons of freight and 20,000 troops and equipment per month; and then note the fact that on one July day nearly 35,000 troops were landed at this same port in eleven hours and forty minutes—the outstanding genius of the Chief of these operations is self-evident. Countless obstacles were fought from the very beginning to the end of his career at Brest.

After the signing of the Armistice General Harries was relieved from his post at Brest and detailed to command the 87th Division, but had hardly assumed command when an order from the Commander-in-Chief sent him post-haste into Germany as the American Commissioner on the Repatriation of Allied Prisoners of War. This appointment—one of the most coveted, if not the most coveted of the post-war Mission-appointments—led the General right to the heart of the enemy's country, Berlin, Germany, which place he reached December 10th 1918, accompanied by two lieutenants and two orderlies; the first American to reach the goal aimed at above all things by every American soldier.

Volumes could be written concerning the important work of the General and his Mission in Berlin—and then the story probably would not be adequately set forth. The greater portion of the General's work was of a diplomatic nature. The nine months of his sojourn in Germany were very busy ones. Then there were many conferences with the heads of the Armistice Commission at Spa, Belgium; much business with the Peace Conference at Paris, with the Supreme War Council, with General Pershing and with Marshal Foch. Aside from this

work, and that of repatriating Allied prisoners of war, General Harries had the unique experience of going through three separate and distinct revolutions in the city of Berlin and witnessing many demonstrations against the Allies and the Peace Treaty and the Allied representatives quartered in the Adlon Hotel in Berlin. He also kept in constant touch with the Germanic political activities during his stay there. His work, during the entire nine months, was carried on in the midst of a hot-bed of political dissension, strikes, riots and revolution—about which the people of the United States know very, very little because of the fact that it was practically impossible for them to get authentic accounts of happenings out of the country at that time.

In recognition of his services overseas, both in France and Germany, General Harries has been the recipient of many decorations from foreign governments, chief among which is that of Commandeur of the French "Legion of Honor." His most highly prized decoration, however, is the Distinguished Service Medal of the United States of America awarded him for his conspicuously successful and meritorious work both at Brest and Berlin.

ANNUAL ELECTION.

GENERAL OFFICERS.

At the Council meeting on June 11th the Committee of Tellers reported the election of officers for the fiscal year, 1920-1921, this report being confirmed by the Council, who announced to the technical press, election of the following officers to take office October 1st, succeeding the present officers whose terms expire on that date.

President:
General George H. Harries

Secretary:
Clarence L. Law

Treasurer:
Louis B. Marks

Vice-Presidents:
H. F. Wallace
Dr. George S. Crampton
J. J. Kirk

Directors:
Adolph Hertz
Walton Forstall
Frank S. Price

NEWLY ADOPTED AMENDMENTS.

I. Providing for student members.

II. Lowering the age limit for associate members from 21 to 18 years; providing for affiliates in Sections and Chapters.

III. Increasing dues of associate members from $5 to $7.50, of members from $10 to $15, and raising maximum dues of sustaining members from $250 to $500; also giving the Council authority to fix the annual dues to be charged for student members and for affiliates.

IV. Providing for local chapters.

V. To make future amendments to the Constitution effective Oct. 1st, instead of twenty days after adoption.

It is planned to publish at an early date a new edition of the Constitution and By-Laws embodying these new amendments with By-Laws.

SECTION ACTIVITIES.

NEW YORK.

Meeting—June, 1920.

The monthly meeting of the New York Section was held at the International Cinema-Quipment Center, 7th Avenue and 49th Street, on June 17th at 8:15 P. M. It was Ladies' Night and the meeting was preceded by a dinner at Churchill's.

A very interesting paper was presented by Mr. E. L. Bragdon of the *Motion Picture News* entitled, "Opportunities for the Illuminating Engineer in the Motion Picture Industry." Following this was a demonstration by the Pathescope Company of America showing their portable projector using the safety standard film. There was also an interesting talk on "How Prizma Pictures are Made," by a Prizma representative and illustrated by a "reel."

The attendance at the dinner preceding this meeting was thirty-four and at the meeting eighty.

New Officers.

Below are given the names of the officers elect for the New York Section for the year 1920-1921, as announced at the Council meeting on June 11th.

Chairman:
Dr. Ralph E. Myers

Secretary:
S. W. Van Rensselaer

Managers:
Herman Plaut
Charles Franck
Frank R. Barnitz
C. A. Barton
H. V. Bozell

NEW OFFICERS.

CHICAGO.

Announcement of the election of officers for the Chicago Section was made at the meeting of the Council on June 11th.

Chairman:
J. L. Stair

Secretary:
J. J. Kirk

Managers:
F. F. Fowle
J. W. Foster
E. D. Tillson
F. T. Benson
A. T. Hunt

PHILADELPHIA.

New section officers for Philadelphia announced at Council meeting of June 11th. The new officers to assume their duties on October 1st.

Chairman:
C. E. Clewell

Secretary:
H. B. Andersen

Managers:
Dr. Howard Lyon
G. Bertram Regar
Herman Eckstein
C. S. Snyder
J. B. Kelley

NEW ENGLAND.

The new Board of Managers and officers for the New England Section were elected to take office October 1st. The announcement at the June 11th Council meeting is given below.

Chairman:
N. W. Gifford

Secretary:
J. T. Kerens

Managers:
J. W. Cowles
F. A. Gallagher, Jr.
L. T. Troland
C. M. Halstead
David Crownfield

SAN FRANCISCO BAY CITIES CHAPTER.

The Council at its meeting on June 11th unanimously authorized the organization of the above named chapter.

The first meeting was held on June 29th, at which twenty members were present. Temporary officers and a Board of Managers were elected to serve until the regular election in October. It is planned to have a joint meeting with the National Traffic Officers' Association at their Convention in San Francisco, August 23rd to 27th for discussion of automobile headlights. Dr. Clayton H. Sharp has been appointed by the Council as special delegate to this Convention.

Temporary Officers.

Chairman:
Leonard E. Voyer

Treasurer:
J. A. Vandegrift

Secretary:
H. H. Millar

Board of Managers:
Miles Steel
W. W. Hanscom
Romaine Myers
R. L. Prussia
L. P. Lowe

COUNCIL NOTES.

ITEMS OF INTEREST.

Meeting—June 11, 1920.

Upon recommendation of the Board of Examiners, the following were elected to membership:

Three Members.

HERMAN PLAUT,
Partner,
L. Plaut & Co.,
Black & Boyd Mfg. Co.,
Mfr. Lighting Fixtures,
432 E. 23d Street,
New York, N. Y.

CHARLES A. BARTON,
General Sales Manager,
New York & Queens Elec. Lt. & Power Co.,
Electric Bldg., Bridge Plaza, N.,
Long Island City, N. Y.

LEROY STEWART FOLTZ,
Professor of Electrical Engineering,
Colorado Agricultural College,
Fort Collins, Colo.

Five Associate Members.

ELLSWORTH FRANCISCO,
Supervisor of Gas Street Lighting,
City of Newark,
City Hall,
Newark, N. J.

LEONARD V. JAMES,
Salesman, Lighting Expert,
Bryan-Marsh Division, National Lamp Works,
623 So. Wabash Ave.,
Chicago, Ill.

DONALD MCCARGER,
Electrical Engineer,
P. W. Miller Co.,
407 Northern Pacific Ave.,
Fargo, N. D.

ARTHUR W. MORRISON,
Manager Fixture Dept.,
United Electric Supply Co.,
579-81 Atlantic Ave.,
Boston, Mass.

FRANK VAN GILLUWE,
Illumination Specialist,
Western Electric Co.,
Sixth and Cary Sts.,
Richmond, Va.

(Subject to Approval of Board of Examiners.)

Three Members.

DAVIS H. TUCK,
Illuminating Engineer,
Holophane Glass Co.,
340 Madison Ave.,
New York, N. Y.

JOHN NASH IVES,
Electrical Engineer,
Lockwood, Greene & Co.,
245 State St.,
Boston, Mass.

(New Member Enrolled in San Francisco Bay Cities Chapter.)

RAIMON F. CONLISK,
Westinghouse Electric & Mfg. Co.,
Fist National Bank Bldg.,
San Francisco, Cal.

One Transfer.

HAROLD W. HAHN,
Sales Engineer,
Duplex Lgt. Works of G. E. Co.,
6 West 48th St.,
New York, N. Y.

Four Associate Members.

FRED T. BANGS,
Managing Editor,
Electrical Review,
53 W. Jackson Blvd.,
Chicago, Ill.

Robert Seton Logan,
Electrical Engineering,
511 St. Catherine St., W.,
Montreal, Canada.

Gertrude H. Shearer,
Lecturer and Publicist,
Philadelphia Electric Co.,
1000 Chestnut St.,
Philadelphia, Pa.

Frank Leslie McKowen,
Assistant Statistician,
Victoria Falls & Transvaal Power Co., Ltd.,
Johannesburg, Transvaal,
South Africa.

(New Associate Members Enrolled in San Francisco Bay Cities Chapter)

Nine Associate Members.

Willis G. Gordon,
Salesman,
Pacific States Electric Co.,
575 Mission St.,
San Francisco, Cal.

Fred Lloyd Peale,
Sales Agent,
General Electric Co.,
Rialto Bldg.,
San Francisco, Cal.

Cyril Barton Nelson,
Illumination Specialist,
Elec. Railway & Man. Supply Co.,
36 Second St.,
San Francisco, Cal.

George W. Ashlock, Jr.,
Electrical Contractor,
Spencer Electric Co.,
355 Twelfth St.,
Oakland, Cal.

Morris Claton Hixon,
Building Equipment Specialist,
General Elec. Co.,
San Francisco Office,
Rialto Bldg.,
San Francisco, Cal.

Eugene W. Garcia,
Salesman,
Edison Lamp Wks. of G. E. Co.,
Room 801, Rialto Bldg.,
San Francisco, Cal.

Earl Pliny Markee,
Mazda Lamp Salesman,
Edison Lamp Works,
Rialto Bldg.,
San Francisco, Cal.

Elmer Zimmerman,
Lighting Equipment Specialist,
Pacific States Electric Co.,
575 Mission St.,
San Francisco, Cal.

Frank D. Fagan,
District Sales Manager,
Edison Lamp Works,
805 Rialto Bldg.,
San Francisco, Cal.

Other Changes in Membership.—

One Associate Member Resigned.

(Resignation accepted subject to payment of dues.)

Robert P. Burrows,
Electric Sales & Engineering Co.,
813-823 Prospect Ave.,
Chicago, Ill.

COMMITTEE ACTIVITIES.

COMMITTEE ON EDUCATION.

At the June Council meeting the Committee on Education presented a very definite plan for beginning immediate publication of an extension or correspondence course in illumination, which it is proposed to circulate through universities having extension courses and through correspondence schools already established. It is estimated that the cost of publishing the completed course in quantities deemed advisable by the Committee on Education will be approxi-

mately $10,000. A fund of $2,500 has already been made available for this work through the efforts of President Doane and more is promised as needed.

Mr. Vaughn, at Prof. Caldwell's request, also gave a general progress report for the Committee on Education. Report was accepted, as given below.

Report of Committee on Education.
Read before the June Council Meeting.

The committee is organized as follows:

F. A. Vaughn, Chairman of Subcommittee on Extension Work.

C. F. Scott, Chairman of Sub-committee on Technical Schools and Colleges.

F. A. Grohsmeyer, Chairman of Subcommittee on Popular Education.

A. L. Powell and W. M. Skiff, Field Members.

F. C. Caldwell, Chairman.

It was the expectation that the chairmen of the subcommittees would select two or three members each for their subcommittees. This, however, has not been officially done. Messrs. Vaughn and Scott have enlisted the assistance of other members of their college staffs. Mr. Grohsmeyer has made considerable efforts to get the cooperation of a representative of the gas lighting interests, but at last reports had not been successful.

Forty-six other members of the Society, chiefly teachers, have consented to serve as corresponding members of the committee to advance its work in their respective sections of the country.

The committee has held two meetings, one in New York on Dec. 11th and 12th, and one in Columbus on April 5th.

The time has not seemed ripe to appoint a subcommittee to take up the matter of education in the public schools. We now have a subcommittee on "Technical Schools and Colleges" as well as one on "Popular Education."

The Committee has so far made some progress along four lines as follows:

1. The development of an extension course in illumination for use by those who are connected with the lighting industry. A definite plan along this line which the committee has asked the Council to approve.
2. The development of interest in illumination among college and technical school instructors and the collection of data with regard to the instruction now being given along these lines.

   Inquiries made by Messrs. Powell and Skiff on the occasion of visits to the colleges brought out certain facts in particular. Such instruction is generally very limited in extent and is variable in character depending upon the especial interests of the instructors. In short, it is in need of extension standardization and modernization.

   At the April meeting of the committee it was decided to send a communication to representatives of the Electrical Engineering and Physics Departments of all the more important colleges of the country, calling their attention to the importance of illumination education and asking for information about their present activities along these lines. A mailing list for this purpose has been completed. It is planned to construct in this way a list of all interested educators, and to maintain connection with these through occasional bulletins. From this list also the number of corresponding members will be increased.
3. Mr. Grohsmeyer has been collecting material for a popular illustrated lecture on "Industrial Illumination." Thanks especially to Mr. Powell and the Cooper-Hewitt Electric Company, considerable material is already in hand and the lecture will be ready for use

before the end of the year. Delay has been experienced in obtaining material with regard to industrial gas lighting.

4. The committee believes that it can cooperate with the Research Committee in bringing to the attention of university instructors, investigations that particularly lend themselves to being carried out under university conditions. They also hope to promote such research. With this end in view a list of subjects is being prepared which will be ready for distribution before the beginning of another college year.

The request of the Council that the report of the 1914 Committee on Education be revised is receiving attention, the material already being collected will serve to bring up to date the portion of that report which deals with "A Summary of Educational Status of Illuminating Engineering." The part concerning "Books on Illumination" is more difficult to arrange for, because of the necessity of access to a complete library. The Chairman has taken this matter up with Mr. Skiff in the hope of enlisting the services of someone who may have access to the Library of the Nela Research Laboratory.

It is expected that the committee will hold one more meeting during July in Ohio.

Suggestions with regard to the work will be appreciated.

Respectfully submitted,
F. C. CALDWELL,
For the Committee on Education.

CONFIRMATION OF APPOINTMENTS.

The following appointments were confirmed at the June Council meeting:

Committee on Artistic Treatment of Interior Lighting.

Additional Members:

Herman Plaut,
432 E. 23d Street,
New York, N. Y.

Gertrude Shearer,
1000 Chestnut Street,
Philadelphia, Pa.

New Local Representatives.

G. O. Hodgson,
Edison Lamp Works,
Denver, Colo.

L. J. Hinwood
Cor. Queen and Little Collins Street, Melbourne, Australia.

COMMITTEE ON EDUCATION.

New Corresponding Members.

D. S. Anderson
Albert L. Arenberg
W. E. Barrows
Edward Bennett
Morgan Brooks
W. H. Browne
O. H. Caldwell
H. E. Clifford
Terrell Williams Croft
W. A. Durgin
F. M. Feiker
A. H. Ford
Chas. Franck
O. J. Ferguson
L. O. Grandahl
H. G. Hake
H. H. Higbee
G. G. Hitchcock
J. A. Hoeveler
E. P. Hyde
D. C. Jackson
D. R. Jenkins
Roy Kegerris
A. E. Kennelly
C. D. Knight
C. L. Law
M. G. Lloyd
C. O. Mailloux
C. M. Masson
L. B. Marks
A. S. McAllister
F. J. Meyer

P. S. Millar
F. H. Murphy
F. A. Osborn
W. L. Robb
F. A. Rogers
H. J. Ryan
G. C. Shaad
R. E. Simpson
L. C. Spake
L. B. Spinney
J. L. Stair
C. W. Waggoner
A. M. Wilson

Program Group Committee on Papers.
New Member:
F. C. Taylor

NEWS ITEMS.

1920 CONVENTION.

Headquarters, Statler Hotel, Cleveland, Ohio.

October 4th to 7th inclusive.
Local Committee Chairmen:

J. E. North, General Convention Committee,
Cleveland Electric Illuminating Co.

Wm. M. Skiff, Vice-Chairman,
National Lamp Works.

G. E. Miller, Reception Committee,
Cleveland Electric Illuminating Co.

H. A. Green, Publicity Committee,
National Carbon Co.

J. M. Smith, Entertainment Committee,
Ivanhoe Regent Works.

George Milner, Finance Committee,
Erner Electric Co.

NOTE FROM PRESIDENT DOANE.

Every Illuminating Engineer will reap a very considerable benefit if he will attend the Cleveland Convention, October 4th to 7th inclusive this year. I know this from the plans and papers discussed at the Convention Committee Meetings that I have attended.

S. E. DOANE, *President.*

LIGHTING THE LOBBY OF ENGINEERING SOCIETIES BUILDING.

The General Secretary received a letter from the United Engineering Society, inviting the Society to contribute to the work of furnishing the hall of the Engineering Societies Building as a reading and reception room, by giving advice in the matter of illumination.

Motion was made and carried at the June Council meeting that a committee be appointed to meet with the committee of the Engineering Societies Building and give them any assistance possible in the way of advice.

It was the opinion of the Council that the Society should not make a rule of acting as Consulting Engineers in the designing of lighting, but that in the present instance an exception should be made.

PERSONAL MENTION.

Mr. L. C. Spake, Chairman of the Membership Committee, has removed from Chicago to the New York Office of the McGraw-Hill Publishing Company and is changing from editorial work to other duties on the business staff of the *Electrical World.* He is succeeded by Mr. S. N. Clarkson and Mr. J. C. Martin.

PURE RED LIGHT CADMIUM-VAPOR ARC.

Scientific Paper No. 371, Bureau of Standards, Washington, D. C., describes a new method of producing a cadmium-vapor arc of great brilliancy by using a cadmium gallium alloy. The cadmium lamp may be operated with a current of three amperes and gives best results when operated at about 25 volts under this condition practically pure cadmium spectrum is obtained. It is expected that there will be a real demand for a light source of this character.

QUESTIONNAIRE TO COLLEGES AND TECHNICAL SCHOOLS.

President Doane urges members to assist the Committee on Education in obtaining replies to the questionnaire recently mailed to colleges and technical schools. Prof. Scott, Chairman of the sub-committee on Colleges and Technical Schools, and Prof. Caldwell, Chairman of the Committee on Education, are to be most heartily congratulated on this circular. Members are requested, as opportunity may offer, to bring it to the attention of their alumni associations and their Alma Maters, recommending that prompt answer be forwarded. The questionnaire and the letter accompanying it is reprinted below.

ILLUMINATING ENGINEERING SOCIETY
EDUCATIONAL QUESTIONNAIRE.

1. Name of institution.
2. Subjects taught (*e. g.*, illumination, photometry, lighting, wiring).
3. Department or college in which the instruction is given.
4. The year, the number of weeks and the hours per week.
5. The principal topics or subdivisions and the approximate percentage of the time devoted to each.
   - Physics of Light.
   - Photometric Measurements.
   - Principles and Theory of Illumination.
   - Illuminants.
   - Physiology and Psychology of Illumination.
   - Lighting Accessories.
   - Interior (Mercantile, Decorative and Residence) Lighting Practice.
   - Industrial Practice, etc.
6. Principal text books or other material used in instruction.
7. Statement of methods of presentation found useful.
8. Theses or special investigations.
9. General remarks.

LETTER.

To the Educators of America:

Have you ever stopped to realize that wonderful part illumination plays in our daily and economic life? Do you devote a sufficient part of your time as a teacher to outlining the fundamental principles of correct lighting?

From a humanitarian standpoint good and proper illumination makes for easy vision, adds to the attractiveness and comfort of our homes and work places, and assists in reducing the number of accidents. On the other hand, poor illumination causes eye strain, reduces the ability to see and if the conditions are very severe may cause permanent injury to the eye.

From an economic standpoint correct lighting in the shop increases production and reduces spoilage. Proper street lighting makes possible a smaller police force and lessens crime. The use of an incorrect and inefficient type of lighting installation may give very much less illumination for a given expenditure than might have been obtained with a proper understanding of the principles involved.

From an educational standpoint illumination offers a unique opportunity for showing the co-ordination of many and

varied factors toward a common purpose. For example, it directly relates to the principles of physics and chemistry; the power producing and transmitting apparatus of the mechanical and electrical engineer; the production of light in various quantities and qualities and forms; the production of illumination by the reflection and distribution of light; the adaptability of various methods of illumination to various specific purposes; illumination as a factor in safety and in economic production; the relations of illumination to the eye, to health, to comfort and to pleasure. The more rigid laws of science and engineering must adapt themselves to the universal need for illumination under indefinitely varying conditions where good judgment or artistic taste may be the determining factors.

The lighting industry is a large and important one. Are you giving the principles of good lighting the attention the subject deserves in comparison to the time devoted to thermodynamics, machine design and other subjects? Several hundred million dollars are spent annually for electric illumination. A considerable proportion of the work of electrical manufacturing companies and of the output of central stations is devoted to illumination. Are you devoting a corresponding proportion of the time allotted to the divers applications of electricity to the lighting art?

The ILLUMINATING ENGINEERING SOCIETY organized in 1906 for advancing the theory and practice of illuminating engineering has become a center for the discussion and exchange of questions on light and illumination and an active factor in disseminating knowledge relating thereto. It embraces in its membership architects, engineers, municipal authorities, teachers and representatives of lighting and manufacturing companies who are interested in the hygienic, esthetic and commercial standpoints.

The Committee on Education is one of the subordinate groups of the Society whose purpose is to extend the knowledge of illumination primarily through educational avenues, one of which is encouraging and aiding in instruction in illumination in colleges and engineering schools.

It is the purpose of the Committee to issue bulletins from time to time presenting phases of the subject which seem most vital and to assist by suggestions in planning and aiding in the work of instruction.

Replies to the foregoing queries will give a fair indication of what is being done now and should afford valuable suggestions as to the future.

It is proposed to send you a summary of the returns received.

It is likely that much instruction in illumination is given incidentally in connection with other courses although there may be no formally prescribed course in illumination.

Your interest and co-operation are invited.

Very truly yours,
COMMITTEE ON EDUCATION,
F. C. CALDWELL, *Chairman.*

EDITORIAL COMMENT FROM THE JULY 10TH ISSUE OF THE ELECTRICAL REVIEW.

Real Illumination in the Home.

Homes for the family are being advocated on every hand, and in many places homes are actually being built in large numbers to overcome the great shortage of housing resulting from long-deferred construction. Unfortunately, some of the larger building programs are being carried through without properly providing for illumination or the other electrical conveniences and necessities on what would be considered a modern basis. Permanent homes now being built will still be in use many years from to-day, and the conveniences of the present will become the necessities of to-morrow.

The artificial lighting of a house has more influence in making it into a home than any other individual feature. The family in the city is seldom assembled during the daylight hours, so that it is in the evening and under the influence

of artificial light that the home comes into its own and draws together the bread-winner and his family. Good lighting eases the tired eyes and allows the body to come to repose and be refreshed in rest, while poorly arranged artificial light has just the opposite effect and defeats the very purpose of an otherwise comfortable home.

Managing organizations directing the home building campaigns have memberships composed of business men, bankers, material dealers, real estate men, building labor representatives and social workers, but no illumination experts. Good artificial illumination can save more priceless eyesight than can ever be corrected after once impaired, and the cost of installing correct home illumination is less than simply attending to one case of impaired vision, to say nothing of the immense loss in comfort and physical efficiency resulting from failing sight. Why not take a truly worthy illuminating expert on the housing boards and make use of the best that can be had just to save the efficiency of the present and future workers, if for no other or more worthy purpose.

NATIONAL SAFETY NEWS.

An editorial on "Light and Safety" appears in the June 7th issue of the *National Safety News.* This editorial by Mr. C. W. Price, General Manager of the National Safety Council, is a very excellent exposition of the relation between light and safety and is exactly in line with the efforts of our Society and must be considered as splendid co-operation.

SCHOOL LIGHTING CODE.

The Industrial Commission of Wisconsin, having successfully adopted industrial and automobile headlighting codes, is now taking up the matter of a school lighting code. An advisory committee for this purpose is being formed under the direction of Mr. J. A. Hoeveler, electrical engineer, for the Commission.

BROADWAY AT NIGHT FROM THE CONTRIBUTORS' CLUB.

There is, certainly, nothing natural about Broadway at night, in the sense that is in any way an imitation of nature. But there is nothing natural, for the matter of that, about an incandescent bulb. Its nearest approach in nature is a Bartlett pear. On the other hand, Broadway at night is profoundly natural. If the evolution of signboards lining American railroads and highways from coast to coast, of placards adorning all our steam and trolley cars, of advertising pages supporting all our newspapers and magazines, is an expression of national development and character; and if the invention of the electric light and the development of electric power are signs of the national resourcefulness and instinct to make the most of physical forces (as we are assured is the case); then what is more natural, more an honest and inevitable race-expression, than Broadway at night? It is evolution blazing its reality from the housetops. It is racial truth. Therefore it is beauty—*vide* Keats.

Barbaric is the adjective some people apply to Broadway. But it is at least a jolly barbarity. I stood the other night looking northward from Forty-second Street, into a narrowing canon of illumination. Against the sky huge electric kittens pursued an endless thread; six gnome-like figures underneath a canopy of colored lights practiced calisthenics, grinning amiably the while; a gentleman forty feet tall stood unashamed against the subordinated stars, clad in an electric union suit, a vast toothbrush was pyrotechnically pro-

phylactic; at last, walling in the vista where Broadway turned, a giant blood-red bull reared his golden horns. And these signs were but a few amid the myriad, some pictorial, vast, and static, some restlessly appearing and disappearing, some merely the blazing names of this or that theatre and play or player.

Keats said that his name was writ in water, but the name of the Broadway star is writ in fire. He obeys the ancient stellar injunction to twinkle. Out of all this welter of illumination, from curb-line to sky, beneath and between which the endless black stream of cabs and cars and sidewalk throngs move like a slow river, the eye, after all, picks out far less the individual sign than the general radiance and lacy pattern of gold. When the individual sign does hold the attention, it is less to remind us of its artistic limitations of design than of its quaint relation, through the thing it advertises, to our national life. It makes us smile—at least, it makes me smile. Why, for instance, when so many jaws in the thousands of faces streaming past on the curb below are busily at work upon a piece of gum, should not the six gum-sprites overhead dance with joy? It is highly fitting. It is, indeed, symbolic. Why, again, when so many thousand motor-cars are passing in endless streams on the asphalt below; when the possession of a motor-car is so essential to the happiness of the average man; when the discussion of motor-cars is the one topic upon which you can start a safe conversation with any stranger in the Pullman smoker—why, then, should not a vast motor-car revolve its incandescent wheels aloft, advertising not so much any particular make of car, as the absorbing national passion?

Broadway at night shows nothing so harsh as poles and wires. Its criss-crossed designs are formed by living lights, designs which are deepened by the dark sky behind them, softened by the haze of their own radiance, made living and lively with color and motion. A wet night on Broadway! How the asphalt glistens with a thousand golden reflections! How the great signs up aloft stab into the mist till, like King Arthur's helmet, they make all the night a stream of fire! How they dim again when the mist is low, or the thick snow is driving past, swirled through the cañoned street! How they seem to lift their radiance to the low roof of the sky above, turning it a dully glowing red! How they call to the spirit, proclaiming crowds, proclaiming mirth and the escape from care into the joyous world of make-believe, of dance and song!

Thunder against Broadway never so hard, call it crude and callous, reckless and extravagant, thoughtless and dissipated; brand its blazing bulls and dancing gum-sprites as the last word in economic idiocy; play the Puritan and the prude, or play the æsthete and the recluse—it is little I care. When I turn into Broadway by night and am bathed in its Babylonic radiance, I want to shout with joy, it is so gay and beautiful. I melt into the river of pleasure-seekers; slowly I flow along to my chosen theatre; before I have even entered the portal, I am in the mood for a play. If I had to reach it through a pine grove or a gallery of Rembrandts, I should never get there, or want to enter if I did. No, Broadway is profoundly right—and therefore beautiful!

The Edward Longstreth Medal of Merit has recently been awarded by the Franklin Institute to M. Luckiesh, a member of this Society, for his paper "The Visibility of Airplanes," printed in the March and April, 1919, issues of the *Journal of the Franklin Institute*.

PROFESSIONAL OPPORTUNITIES.

Note.—Beginning with Volume XV, No. 1, the General Office have been publishing details of business opportunities which have come to the office, with such success that it is now proposed to offer to our members, the facilities of this column under the heading of "Services Available." Advertisements sent in by members not exceeding fifty words will be printed without charge, such copy is not to be printed oftener than three issues per year for each member.

Illuminating Engineer to prepare correspondence course in Electric Lighting and also to correct papers. Teaching experience desirable, but the ability to explain in writing is essential. Must be located near New York City. Z-1235

Junior Illuminating Engineer wanted by large public utility company in Western New York. Capable of advising on all problems of general lighting practice. Sales experience desirable, although this company does not merchandise lighting fixtures or equipment. Age 25 to 30. $1800 per year subject to adjustment at the expiration of first three months.

Z-1717

Young Men for Sales Department, with some business experience, and some technical education. Work will consist of course in Engineering Department at factory, covering brief apprentice course in testing and Engineering Department, especial emphasis being laid on illumination. This course will take a year or more and fit the candidate for outside sales work. Location New Jersey.

Z-1493

Old Copies Wanted.

Wanted—a few copies of the following issues of TRANSACTIONS.

General Office will pay fifty cents ($0.50) per copy.

Volume One—
- No. 1
- No. 2
- No. 3

Volume Two—
- No. 1
- No. 3
- No. 4

Volume Three—
- No. 1
- No. 2
- No. 4

Volume Eight—
- No. 7
- No. 8
- No. 9

Volume Nine—
- No. 2

Volume Fourteen—
- No. 2

BOOKS.

"Artificial Light"—M. Luckiesh, published by the Century Company, New York City, 1920. 366 pages with index and 40 illustrations.

The author, who is Director of Applied Science at the Nela Research Laboratory of the General Electric Company, has compiled the results of his years of experience in the lighting field. In the first four chapters the author describes light and progress in the primitive days; passing from that into the early lighting with oil and gas illuminants. He then considers the science of light production, under the different headings of gas lighting, electric arc lighting, electric incandescent lamp, and discusses the psychology of light and the possibilities for more efficient illuminants in the future. There are numerous descriptions of present day application of lighting and discussions of illumination as it affects the people generally from questions of health to cost of living.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Untersuchungen uber die zweckmaszigste Verwendung von Gluhlampen fur die Beleuchtung von Bahnhofsanlagen—		Feb. 26	181
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British Standard Specification for Goliath Lamp Caps and Lamp Holders (from British Eng. Standards Assn., No. 98, Dec., 1919, p. 4)—		May	12a
Shadowless Illumination (from Nature (Paris), No. 2390, Jan. 17, 1920, p. 48)—	A. Breton	May	24a
Developments in Electric Lamps for Shop Use (from Am. Mach., 51, No. 19, Nov. 6, 1919, p. 821)—		May	24a
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Commercial Gas Lighting—	C. A. Pepper	May	119
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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV | AUGUST 20, 1920 | No. 6

CONVENTION NOTES.

The fourteenth Annual Convention of the Illuminating Engineering Society will be held in Cleveland, Ohio, October 4th to 7th (Monday to Thursday, inclusive). Convention headquarters will be at the Statler Hotel.

General Convention Committee.

J. E. North, Chairman—Cleveland Electric Illuminating Co.
Wm. M. Skiff, Vice-Chairman—National Lamp Works of General Electric Co.
S. C. Hansen, Secretary—Cleveland Electric League.
H. W. Morrison—Lynn Gas & Electric Co.
Otis L. Johnson—Benjamin Electric Manufacturing Co.
Adolph Hertz—New York Edison Co.
H. A. Hornor—Buckingham Valley, Bucks County, Pa.
William J. Clark—Westchester Lighting Co., Mt. Vernon, N. Y.
Preston S. Millar—Electrical Testing Laboratories.
F. E. Miller, Chairman, Reception Committee—Cleveland Electric Illuminating Co.
H. A. Green, Chairman, Publicity Committee—National Carbon Co.
J. M. Smith, Chairman, Entertainment Committee—Ivanhoe Regent Works.
Geo. Milner, Chairman, Finance Committee—Erner Electric Co.
G. S. Black, Chairman, Attendance Committee—Cleveland Engineering Society.
J. L. Wolf, Chairman, Registration Committee—Builders Exchange, Cleveland, Ohio.
A. M. Collins, Chairman, Hotel Committee—Western Electric Co., Cleveland, Ohio.

Program.

Monday Morning:
Registration.

Monday Afternoon:
Opening Session.

Monday Evening:
President's Reception and Dance.

Tuesday Morning and Afternoon:
Presentation of Papers and Discussion.

Tuesday Evening:
Paper and Home Lighting Demonstrations.

Wednesday Morning and Afternoon:
Presentation of Papers and Discussion.

Wednesday Evening:

Banquet.

Thursday Morning:

Papers and Address of Incoming President.

Tentative Papers Program*—1920 Convention.

Monday Afternoon, October 4th:

President's Address..S. E. Doane
Report of General Secretary..................................Clarence L. Law
Progress as Reported in the Literature of Illuminating Engineering
Committee on Progress, F. E. Cady, Chairman
The Society's Educational Program...... ... ...
Committee on Education, F. C. Caldwell, Chairman
I. E. S. Headlighting Specifications
Committee on Automobile Headlighting Specifications,
C. H. Sharp, Chairman

Tuesday Morning, October 5th:

Modified Views on the Theory of Light........................E. F. Nichols
Some Applications of the Photoelectric Cell..................W. E. Story, Jr.
Knowns and Unknowns of Light Production.................G. M. J. Mackay
Optical Principles in Illuminating Engineering..................P. G. Nutting
Measurements of Reflection Factors.............C. H. Sharp and W. F. Little

Tuesday Afternoon, October 5th:

**Knowns and Unknowns of Illuminating Principles
Auspices Committee on Papers
Effect of Variations of Intensity of Illumination on Functions of
Importance to the Working Eye................C. E. Ferree and G. Rand
Notes on Department Store Lighting..............................J. Daniels

Tuesday Evening, October 5th:

Pleasing Proportions of Direct and Diffused Light..............J. R. Cravath
**Home Lighting Demonstrations...............Auspices National Lamp Works

Wednesday Morning, October 6th:

The Problem of Brightness......................................Bassett Jones
Central Station Methods for Securing High Lighting Standards in
Stores and Homes..............O. R. Hogue, J. J. Kirk and E. D. Tillson
Some-Out-of-the-Ordinary Applications in Mill Work...........S. G. Hibben
An Improved Method for the Illumination of Motion Picture Theatres
L. A. Jones
Recent Applications of Color in Lighting..........A. D. Curtis and J. L. Stair

* It is expected that some few additions will be made to this program and these will be announced later.

** Not definitely arranged.

Wednesday Afternoon, October 6th:

The Society's Work Among Other Organizations
Committee on Reciprocal Relations, Ward Harrison, Chairman
The High Cost of Poor Lighting..................................R. E. Simpson
A New Form of Light Meter..................................Davis Tuck
**Further Statistics on Street Accidents........................Ward Harrison

Thursday Morning, October 7th:

Central Station Experience in the Improvement of Factory Lighting
J. B. Wilson
Lighting of Shoe Factories.................A. L. Powell and J. H. Kurlander
Address of President-Elect..........................Gen'l. Geo. H. Harries

Chairman G. H. Stickney of the Committee on Papers states that the outlook is very bright for an excellent series of sessions at the Convention, as there will be several very interesting scientific papers, in fact, the proportion of scientific papers will be higher than in the past.

** Not definitely arranged.

COUNCIL NOTES.

ITEMS OF INTEREST.

Upon the recommendation of the Board of Examiners, the following were elected to membership at the July 15th and August 4th meetings of the Council:

Five Members.

HERBERT C. DOUGHTY
General Superintendent,
Hammonton Gas & Electric Co.,
225 Bellevue Ave.,
Hammonton, N. J.

ROBERT L. ELTRINGHAM,
Electrical Engineer,
Industrial Accident Commission of the State of California,
210 Underwood Bldg.,
San Francisco, Cal.

WILLIAM M. GILBERT,
Optometrist,
Prof. of Theoretic Optics and Math. at the Penn State College of Optometry,
Bourse Bldg., 5th and Market Sts.,
Philadelphia, Pa.

JOHN LEUTHOLD,
Publisher Summit County *Star*,
Masonic Bldg.,
Breckenridge, Colo.

LOUIS W. MOXEY, JR.,
Vice-President and Engineer,
Keller-Pike Co.,
1213 Race St.,
Philadelphia, Pa.

Fourteen Associate Members.

P. A. ANDERSON,
Industrial Engineer,
Great Western Power Co.,
1700 Broadway,
Oakland, Cal.

GEORGE E. ARMSTRONG,
Associate Editor, *Journal of Electricity*,
McGraw-Hill Co.,
531 Rialto Bldg.,
San Francisco, Cal.

R. W. AUER,
President, R. W. Auer Electric Co.,
247 S. Sixtieth St.,
Philadelphia, Pa.

F. A. BELDON,
Vice-President and Gen'l. Manager,
Rockingham County Light & Power Co.,
29 Pleasant St.,
Portsmouth, N. H.

ARTHUR F. BUSS,
Building Equipment Specialist,
General Electric Co.,
Rialto Bldg.,
San Francisco, Cal.

ERNEST M. FRELLSON,
Salesman,
Edison Lamp Works, G. E. Co.,
Rialto Bldg.,
San Francisco, Cal.

T. P. GLEESON,
Manager, Illuminating Eng. Dept.,
Commercial Electric Supply Co.,
320 S. Broadway,
St. Louis, Mo.

FRANK J. GLEISS,
Asst. Supt. Elec. Distribution, Oakland District,
Great Western Power Co. of Cal.,
1700 Broadway,
Oakland, Cal.

DAVID EDWARD HARRIS,
Vice-President and General Mgr.,
Pacific States Electric Co.,
575 Mission St.,
San Francisco, Cal.

ALLEN HIGGINS, JR.,
Salesman,
Westinghouse Elec. & Mfg. Co.,
First National Bank Bldg.,
San Francisco, Cal.

HERBERT J. MAYO,
Sales Engineer,
Benjamin Electric Mfg. Co.,
582 Howard St.,
San Francisco, Cal.

J. E. NORTH,
Commercial Agent,
Cleveland Elec. Illuminating Co.,
75 Public Square,
Cleveland, Ohio.

KENNETH C. OGDEN,
Mgr. New Business Dept., Electric,
Westchester Lighting Co.,
First Ave. and First St.,
Mount Vernon, N. Y.

W. L. STOCKWELL,
Manager,
J. C. English Co. of Cal.,
228 Pine St.,
San Francisco, Cal.

Two Transfers to Member Grade.

ROMAINE W. MYERS,
Consulting Elec. and Illuminating Engineer,
204 Bacon Bldg.,
Oakland, Cal.

ROBERT S. PRUSSIA,
District Illuminating Engineer,
Westinghouse Lamp Co.,
701 First National Bank Bldg.,
San Francisco, Cal.

Two Associate Members.

(Subject to the Approval of the Board of Examiners)

H. B. BLANTON,
Manager Lighting Division,
Alexander & Lovenson Electric Supply Co.,
132-8 Second St.,
San Francisco, Cal.

S. P. RUSSELL,
Vice-President,
H. B. Squires Co.,
583 Howard St.,
San Francisco, Cal.

OTHER CHANGES IN MEMBERSHIP.

Three Resignations.

Two Members.

G. M. J. MACKAY,
General Electric Co.,
Research Laboratory,
Schenectady, N. Y.

EDWARD B. MYERS,
Asst. Appliance Engineer,
The United Gas Improvement Co.,
1401 Arch St.,
Philadelphia, Pa.

One Associate Member.

G. WHITNER ROGERS,
Division Manager,
Philadelphia Suburban Gas & Elec. Co.,
West Chester, Pa.

CONFIRMATION OF APPOINTMENTS.

The following appointments were confirmed at the August Council meeting:

Convention Committee.

SUB-COMMITTEE CHAIRMEN.

G. E. Miller, Reception
Electric Illuminating Co.

H. A. Green, Publicity,
National Carbon Co.

J. M. Smith, Entertainment,
Ivanhoe-Regent Works.

George Milner, Finance,
Erner Electric Co.

New Local Representative at Toronto.

W. P. Dobson,
Hydro Elec. Power Co. of Ontario,
8 Strachan Ave.,
Toronto, Canada.

NEWS ITEMS.

REORGANIZATION OF NELA RESEARCH LABORATORIES.

Dr. Ernest Fox Nichols Goes to Nela Park.

Nela Research Laboratory was organized in 1908 under the Directorship of Dr. Edward P. Hyde as The Physical Laboratory of the National Electric Lamp Association. The name was changed to Nela Research Laboratory in 1913, when the National Electric Lamp Association became the National Lamp Works of General Electric Company. For some years the Laboratory was devoted exclusively to the development of those sciences on which the art of lighting has its foundation, but in 1914 the functions of the Laboratory were extended by the addition of a small Section of Applied Science, which had an immediate practical objective.

The Section of Applied Science is now being largely extended as a separate Laboratory of Applied Science under the immediate direction of Mr. M. Luckiesh, who becomes Director of Applied Science, and a new building is being constructed to house this branch of the work, which will be carried forward with a staff of several physicists, an engineer, an architect and a designer, together with the necessary technical and clerical assistants.

Dr. Ernest Fox Nichols, formerly President of Dartmouth College, and more recently Professor of Physics at Yale University, has accepted an invitation to assume the immediate direction of the Laboratory of Pure Science, under the title of Director of Pure Science. The work of this Laboratory, which will be continued in the present building, will be somewhat further extended under the new organization.

The Laboratory of Pure Science and the Laboratory of Applied Science will together constitute the Nela Research Laboratories, and will be co-ordinated under the general direction of Dr. Hyde, who becomes Director of Research.

LICENSING PROFESSIONAL ENGINEERS.

The Society has received a communication from the State Board of Education asking for a list of men competetnt to serve on a State Board of Licensing for Professional Engineers and Land Surveyors and which list will be furnished by the General Secretary.

AUTOMOBILE LIGHTS.

A communication has been received from the National Safety Council asking for a criticism of Lesson 10 (Automobile lights) of their series of twelve lessons on the operating and management of motors. This communication has been referred to the Committee on Automobile Headlighting Specifications.

PERSONAL MENTION.

Mr. J. E. North, Cleveland Electric Illuminating Company, Cleveland, Ohio, was appointed Chairman of the Convention Committee at the suggestion of Mr. Lindsay, who was unable to accept the appointment as chairman of this committee.

Owing to the removal of Prof. J. M. Coahran from Albuquerque, New Mexico, due to the recent death of his wife, he has resigned as Official Representative of the Society in that city.

ELECTRICAL MERCHANDISING EDITORIAL.

The President was requested at the August Council meeting, to communicate with Mr. Marks, Chairman of the Committee on Lighting Legislation, and reply to the Editorial appearing in a recent issue of *Electrical Merchandising*. This editorial discussed the fixing of higher lighting intensities, commenting that the Society has been somewhat slow to publish data in this connection.

August 6, 1920.

To THE EDITOR OF ELECTRICAL MERCHANDISING,
10th Avenue and 36th Street,
New York City.

DEAR SIR:

Your editorial of July, 1920, entitled "Who Will Accept This Responsibility?" on page 31, raises a question on which we have had much discussion in the Illuminating Engineering Society.

The Society has been engaged for a long time in an effort to express our best judgment on the subject. I hope that something can be put out by us in the near future which will answer the needs you have so eloquently expressed.

Yours very truly,
S. E. DOANE,
President.

TECHNICAL BULLETINS.

It was proposed at the August Executive Committee meeting that a series of Technical Bulletins be issued under the joint auspices of a Committee on Technical Publicity and the Committee on Papers, these bulletins to be underwritten by sustaining members interested.

COMMITTEE ACTIVITIES.

REPORT OF COMMITTEE ON CLASSIFICATION AND COMPENSATION OF ENGINEERS.

The General Secretary reported at the Council Meeting on July 15th that at the suggestion of Mr. Marks, Chairman of this Committee, he had written to the Secretary of the Committee on Classification and Compensation of Engineers, Engineering Council stating that inasmuch as this report refers to engineers in railroad, Federal, State and municipal service and does not apply to the vast majority of illuminating and

other engineers that are included in the membership of the Illuminating Engineering Society, that the Society was not prepared to pass judgment on the standards of compensation. He assured the Secretary, however, that he was confident that the engineers in the Society were in sympathy with the stand which the Committee had taken.

THE EDUCATIONAL WORK OF THE ILLUMINATING ENGINEERING SOCIETY.

Progress Report of Committee on Education.

An important part of the business of our members is the sale of good lighting. The principal function of the Illuminating Engineering Society is the promotion of good lighting. It would seem that the close connection of the work of this Society with the interests of the Central Stations is not sufficiently appreciated by those connected with this branch of the lighting industry. An indication of this, as related to our own membership, is that out of the more than twelve hundred members of the Society only three are connected with Ohio Central Stations. Also out of the thirty Utility Companies, which constitute approximately half of the sustaining membership of the Society, only one is located in Ohio. It would be profitable and interesting to tell of many of the activities of this Society and to point out how they advance the interests of Central Stations. Time will only permit me to speak of the work of the Committee on Education, of which I have the honor to be Chairman.

The work of this committee has followed so closely in the footsteps of our O. E. L. A. Committee on Illumination, that it is of especial interest to this body. Mr. S. E. Doane, the President of the Illuminating Engineering Society, and who has also done so much good work in our Ohio Association, has given to the work of this committee his especial interest and support, and it was largely at his suggestion that its work has been divided into four lines, each under the direction of a subcommittee. These are Colleges and Technical Schools, Secondary Schools, Popular Education and Lectures, and Extension Courses. The work in the first two lines is of only indirect interest to Central Station men. Mr. F. A. Grohsmeyer, a member of our Illumination Committee, is chairman of the subcommittee in charge of the popular education work. His principal efforts this year have been devoted to the preparation of an illustrated lecture on industrial lighting. This is one of a series, the manuscript and lantern slides for which, are made available for general use by the Illuminating Engineering Society. It is hoped that this will be ready before fall. Similar illustrated lectures are already available on several other phases of lighting.

It is, however, to the extension course work of the committee that it is particularly desired to call your attention. This may be considered to be a direct outgrowth of the "Technical Letters on Industrial Lighting," which have been published during the past two years by the Electrical Engineering Department of the Ohio State University in cooperation with the Committee on Illumination, of this Association.

This series of extension lessons are being prepared under the direction of Mr. F. A. Vaughn, of the Milwaukee School of Engineering, one of the best known members of the Illuminating Engineering Profession, as well as a suc-

cessful educator. While the details of the plans for their publication are not yet completely worked out, it is decided that the course will consist of a series of lessons or assignments which will be published at frequent intervals and will cover in an elementary way the whole subject of good lighting. These will take up not only the general principles of illumination and the sources of light, but also their application in the different fields of lighting. They will also give particular attention to the economic aspects of illumination. They will differ from the "Technical Letters," in being self contained; but will be similar to them, in that they will be designed especially to meet the needs of those who are already engaged in practical work in connection with the various branches of the lighting industry. While these lessons will be suitable for individual study by those who wish to use them in this way, it is hoped that many educational organizations, conducting night schools and correspondance and other forms of training courses, will avail themselves of the opportunity to obtain such authoritative and up-to-date material. Those who are preparing this series will give their services without cost and the small profit charged above the paper, printing and distribution will be used for the further promotion of similar educational work.

As soon as more definite information with regard to this course is available, a circular letter will be mailed and it is hoped that the Members of the Ohio Electric Light Association will actively cooperate with the Illuminating Engineering Society in bringing this opportunity to the attention of all those whose present or prospective connection with the lighting industry may make needful a practical working knowledge of the principles of good lighting.

PROFESSIONAL OPPORTUNITIES.

Note.—Beginning with Volume XV, No. 1, the General Office have been publishing details of business opportunities which have come to the office, with such success that it is now proposed to offer to our members, the facilities of this column under the heading of "Services Available." Advertisements sent in by members not exceeding fifty words will be printed without charge, such copy is not to be printed oftener than three issues per year for each member.

Illuminating Engineer to prepare correspondence course in Electric Lighting and also to correct papers. Teaching experience desirable, but the ability to explain in writing is essential. Must be located near New York City. Z-1235

Junior Illuminating Engineer wanted by large public utility company in Western New York. Capable of advising on all problems of general lighting practice. Sales experience desirable, although this company does not merchandise lighting fixtures or equipment. Age 25 to 30. $1800 per year subject to adjustment at the expiration of first three months. Z-1717

Young Men for Sales Department, with some business experience, and some technical education. Work will consist of course in Engineering Department at factory, covering brief apprentice course in testing and Engineering Department, especial emphasis being laid on illumination. This course will take a year or more and fit the candidate for outside sales work. Location New Jersey. Z-1493

Old Copies Wanted.

Wanted—a few copies of the following issues of TRANSACTIONS.

General Office will pay fifty cents ($0.50) per copy.

Volume One—
- No. 1
- No. 2
- No. 3

Volume Two—
- No. 1
- No. 3
- No. 4

Volume Three—
- No. 1
- No. 2
- No. 4

Volume Eight—
- No. 7
- No. 8
- No. 9

Volume Nine—
- No. 2

Volume Fourteen—
- No. 2

THE NATIONAL RESEARCH COUNCIL DIVISIONAL CHAIRMEN.

The National Research Council, with headquarters at Washington, has elected the following chairmen of its various divisions for the year beginning July 1, 1920:

Division of Foreign Relations—George E. Hale, Director, Mt. Wilson Observatory, Carnegie Institution of Washington.

Government Division—Charles D. Walcott, Secretary of the Smithsonian Institution, and President of the National Academy of Sciences.

Division of States Relations—John C. Merriam, Professor of Palaeontology, University of California, and President-elect of the Carnegie Institution of Washington.

Division of Educational Relations—Vernon Kellogg, Professor of Entomology, Stanford University, and Permanent Secretary of the National Research Council.

Division of Industrial Relations—Harrison E. Howe..

Research Information Service—Robert M. Yerkes.

Division of Physical Sciences—Augustus Trowbridge, Professor of Physics, Princeton University.

Division of Engineering—Comfort A. Adams, Lawrence Professor of Engineering, Harvard University.

Division of Chemistry and Chemical Technology—Frederick G. Cottrell, Director of the Bureau of Mines.

Division of Geology and Geography—E. B. Mathews, Professor of Minerology and Petrography, Johns Hopkins University.

Division of Medical Sciences—George W. McCoy, Director of the U. S. Hygienic Laboratory since 1915.

Division of Biology and Agriculture—C. E. McClung, Professor of Zoology, University of Pennsylvania.

Division of Anthropology and Psychology—Clark Wissler; Curator of Anthropology, American Museum of Natural History, New York.

THE ILLUMINATION OF COAL MINES.*

BY H. F. BARNES AND J. H. KURLANDER.

The original methods of lighting for the miner employed the ordinary tallow candle or small oil lamp. The illumination given by these flames was meager and was only adaptable to nongaseous seams. In an effort to avoid the use of open flames, unique but rather crude methods were employed to furnish illumination. Fireflies imprisoned in bottles, scales of dry fish skins which were slightly phosphorescent and later the steel mill were some of the schemes. The latter consisted of a steel disc driven by a series of hand operated gears. The sparks given off when a piece of flint pressed against the rim of the disc served as a means of illumination.

Sir Humphrey Davey in 1815 produced a practical safety oil lamp. Most safety lamps used at the present time are modifications of the principles embodied in his original lamp. He enclosed the flame with a thin wire gauze which permitted the light to pass through, but offered such a large radiating surface to the hot gases that before they passed through the gauze they were well below the point of ignition. Such lamps were in universal use when the electric cap lamp was introduced.

The interior of the mine presents a problem which is radically different from that encountered in other industries. Instead of having large areas with relatively high ceilings there are long passageways 12 to 15 ft. wide and but 6 or 7 ft. high, sometimes extending for miles. In the ordinary building dependence is had on the walls for reflection and diffusion of light. In the coal mine with its jet black surroundings the brightness of the light sources must be kept at a minimum. For with the dark background a bright light source becomes blinding.

It is necessary first to install sufficiently large lamps to provide adequate illumination and second to arrange and equip them so that glaring conditions are avoided. This condition is helped if the walls in the vicinity of lamps are whitewashed to prevent a great contrast. Reflectors also serve in hiding the lamp itself.

* Abstract from article appearing in *Electrical Review* of July 10, 1920

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Part I

Fig. 1.—View of foot of shaft showing results that can be attained with the proper use of lamps and reflectors. Two 10 -watt type C lamps in RLM standard dome reflectors suspended from ceiling and 100-watt type C lamps in steel angle reflectors, staggered with reference to RLM domes, hung along walls.

Fig. 2.—View showing switchpoint lighted by two 100-watt type C lamps in angle reflectors One unit lights up the switch point with it's mechanism and the other placed 20 feet farther on projects light onto the junctionpoint in order to give warning to the motorman that he is approching a switch.

Fig. 3.—View of motor repair pit lighted by two 100-watt type C lamps in RLM standard dome reflectors suspended from ceiling. The white walls serve to reflect a large proportion of the light from the lamps thus giving the room a bright appearance.

Fig. 4.—Night view of picking bands in a wet breaker lighted by a row of 200-watt type C lamps in shallow dome reflectors placed over each band. The intensity varies from 8 foot-candles at the head of the band to 2 foot candles at the foot of the band.

At the bottom of the shaft where cars are loaded on the cages, good illumination is required to enable the cars to be switched on the proper tracks and stopped at a definite point. Illumination should also be provided for a considerable distance from the foot of the shaft along the main gangway since cars and motors are continually operating in this area. At the foot of the shaft a combination of angle and dome reflectors is desirable. Angle reflectors with Type C lamps should be placed on the walls as close to the ceiling as practicable and should be spaced approximately 10 ft. apart. An actual installation of this sort is depicted in Fig. 1. In order to meet the demands as outlined above, at least four units are advisable on each side. The reflectors should in general be turned so that they point towards the shaft to prevent glare in the eyes of the locomotive operators who are approaching from the dark mine. This arrangement also reflects light onto the cages. Between each set of tracks and on 10 to 12 ft. centers 100-watt Type C lamp in RLM standard dome reflectors should be placed as close to the ceiling as possible.

At switchpoints two angle units are desirable. One opposite the switchpoint and so placed as to direct the light on the switch mechanism and a second unit in the neighborhood of 20 ft. farther on for directing the light at the junction point. As will be seen in Fig. 2, this arrangement answers the purpose satisfactorily. If the walls comprising the junction point are painted white the effect will be particularly good. The location of the switching point will be visible from a considerable distance and the snapper can perform his work with confidence and safety. The two units can be operated in series from the trolley circuits.

Motor repair pits should receive special attention for it is necessary to make repairs in a minimum of time; if the work is not well illuminated this cannot be accomplished. The motor repair pit of average size will receive sufficient general illumination from two 100-watt Type C lamps in RLM standard dome reflectors hung as high as possible above the center of the track such as shown in Fig. 3. The pit can be well illuminated with 100-watt angle unit in recesses at each side. Portable or hand lamps are necessary to examine the interior of motors and other apparatus.

Coal as it comes from the mine ranges in size from that of dust particles to pieces measuring a foot or more across. Obviously, in the case of anthracite coal it is necessary to grade these pieces in order to meet the demand for market sizes. This grading takes place in the breaker which also reduces the larger fragments to marketable sizes.

Immediately adjoining the head of the conveyor are the picking bands, whereon the large pieces of coal and carbonaceous slate are separated. These bands vary in length from 50 ft. to 20 ft. For illuminating the long picking bands one row of 200-watt Type C lamps in RLM standard dome reflectors placed over each band and spaced about 12 ft. apart will give a good intensity on the work, as will be shown in Fig. 4.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Lighting for County Homes and Village Communities (Official Publication Iowa State College Agriculture and Mechanic Arts, Vol. 18, No. 19, Oct. 8, 1919)—	Wm. Kuerth	June	28a
Military Searchlights (from Proc. Engrs. Western Pennsylvania, 36, No. 2, Mar., 1920, p. 81)—	S. G. Hibben	July	32a
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Journal of the American Chemical Society			
Fluoremetry, Quantitative Analysis by Comparative Fluorescence—	L. J. Desha	July	1350
Journal of Electricity			
The First Arc Lamp in San Francisco—	F. E. Smith	June 15	610
Journal of the Franklin Institute			
Note on the Effect of Lack of Whiteness in the Paint and Window of the Ulbricht Sphere—	F. E. Cady	June	787
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Journal of the Optical Society of America			
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On the Cadmium-Vapor Arc Lamp—	H. J. S. Sand	June	678
Physakalische Zeitschrift			
Uber die Helligkeitsverteilung des diffusen Sonnenlichtes am klaren Himmel (aus Abhandl. d. Mathem.-Physikal. Klasse der Kgl. Sächs. Ges. d. Wissenschaften, Bd. XXXV, Nr. VI, Leipzig)—	Martin Uibe	Apr. 15	224
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Revue Generale de L'Electricite			
Quelques applications des radiations infra-rouges (La Technique moderne, fevrier 1920, t. XII, pp. 85-88)—	L. V. Bournat	May 22	161D
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Radicalism and Research in America—	Neil E. Stevens	July 9	25
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The Organization of Research—	James R. Angell	July	26
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Technical Review			
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Textile World Journal			
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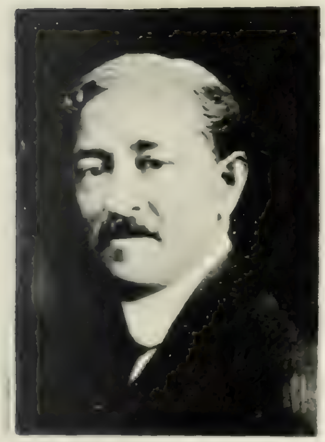
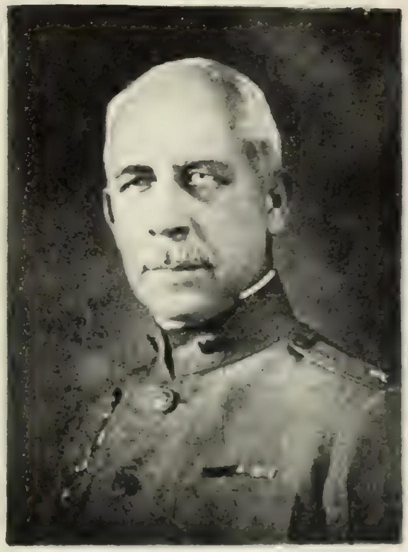
ILLUMINATING ENGINEERING SOCIETY OFFICERS FOR 1920-1921

Left to Right—Top—Dr. Geo. S. Crampton, W. J. Clark, H. F. Wallace, Vice-Presidents.

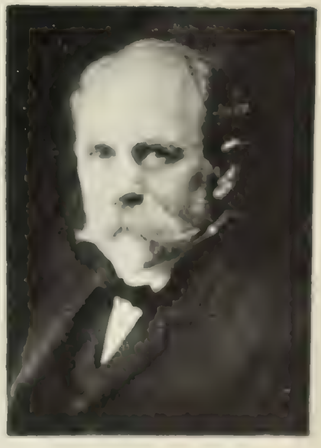
Center—L. B. Marks, Treasurer; Genl. Geo. H. Harries, President; Clarence L. Law, General Secretary.

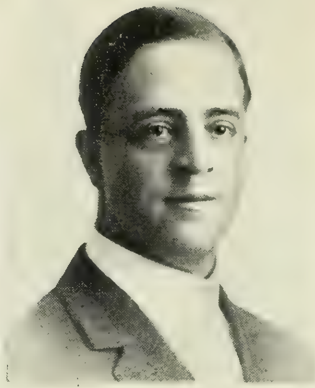
Bottom—S. E. Doane, Past President; J. J. Kirk, Vice-President; Geo. A. Hoadley, Past President.











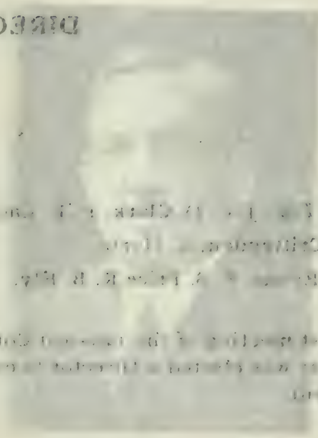
DIRECTORS*

Left to Right—Top—J. C. D. Clark, F. E. Cady, Walton Forstall.
Center—E. C. Crittenden, A. Hertz.
Bottom—E. J. Evans, F. S. Price, R. B. Ely.

*At the first meeting of the 1920-1921 Council held at Cleveland, Ohio on October 16th Mr. P. S. Millar was elected a Director to complete the unexpired term of J. J. Kirk, now a Vice-President.





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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV | OCTOBER 9, 1920 | NO. 7

SECTION ACTIVITIES.

CHICAGO.

The following Committee Chairmen have been appointed for the Chicago Section for the year 1920-1921:

Attendance—J. J. Ryan, City Hall, Dept. of Gas and Electricity, Chicago, Ill.

Membership—R. C. Close, 316 South Wells St., Chicago, Ill.

Reception—A. L. Arenberg, 316 South Wells St., Chicago, Ill.

The Board of Managers have decided to also function as a Committee on Papers, Geo. C. Keech, Chairman.

NEW ENGLAND.

The Board of Managers of the New England Section had their first meeting and determined that they would hold four meetings during the season in November, January, March and May at the Engineers Club, Boston. The program for these meetings is not yet ready for announcement.

NEW YORK.

The 1920-21 Board of Managers of the N. Y. Section have held three meetings since July 22nd. The following Committees have been appointed and the Board looks forward to a very successful season.

Papers Committee:
H. V. Bozell, Chairman
E. N. Caldwell
G. L. Diggles
Sullivan Jones
R. H. Maurer
E. A. Mills
L. C. Porter
L. L. Strauss

Exhibition Committee:
F. R. Barnitz, Chairman
E. A. Sonn
W. G. Marthai

Membership Committee:
Herman Plaut, Chairman
Geo. Widerman
H. L. Graves
W. T. Blackwell
W. A. Kennedy

Attendance and Publicity:
C. A. Barton, Manager
H. A. Tuck
Edgar Ellinger
A. L. Powell
W. R. McCoy

Dinner and Reception:
Charles Frånck, Chairman
S. W. Van Rensselaer
E. L. Bradbury

The first meeting will be held in the Auditorium of the Engineering Society Building, 29 W. 39th St., on October 22, 1920, and will be a joint meeting with the American Society of Safety Engineers. Mr. H. W. Mowery, president of that Society, will preside. It is expected to have short papers on the following topics:

"Defective Illumination, A Cause of Industrial Accidents," by R. E. Simpson.

"Reduction of Accidents Through Visual Acuity," by H. F. J. Porter.

"Elements of Good Industrial Lighting," by S. E. Doane.

"Industrial Lighting Equipment and Its Maintenance," by S. G. Hibben.

"Safety Disconnecting Hanger as a Safeguard," by A. J. Thompson.

For the November meeting it is planned to have a paper on the "Lighting of Schools."

At the December meeting there are plans for papers on "Recent Developments in Flashlights" and one on "Lenses."

A number of subjects have been discussed by the Papers Committee for future meetings and it is planned to publish a program at an early date.

SAN FRANCISCO BAY CITIES CHAPTER.

The San Francisco Bay Cities Chapter meeting held September 24th was most successful. The "Monograph on Illumination" by Past President G. A. Hoadley was presented by his son, Russell Hoadley, and the following took part in the discussion:

Roumaine Myers
J. A. Vandegrift
Clark Baker
H. H. Millar
Miles Steel
Russell Hoadley
L. E. Voyer

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE COUNCIL EXECUTIVE COMMITTEE MEETING.

At the meeting of the Committee held on September 23, 1920, the following were elected to membership.

Eight Members.

FREDERICK HOWE FORD,
Mgr. Lens Dept.,
C. A. Shaler Co.,
Waupen, Wis.

LAWRENCE A. HAWKINS,
Engineer of Research Laboratory,
General Electric Co.,
Schenectady, N. Y.

JOSEPH WARREN HOOKER,
Salesman,
Thomas Day Co.,
725 Mission St.,
San Francisco, Cal.

PROF. BENEDICT F. RABER,
Mechanical and Elec. Eng.,
University of Cal. and Filtration Div., City Comm. (Sacramento),
Berkeley, Cal.

MILTON B. ROLLER,
Designer,
Thos. Day Co.,
725 Mission St.,
San Francisco, Cal.

M. S. SEELMAN, JR.,
Asst. Sales Mgr.,
Brooklyn Edison Co., Inc.,
360 Pearl St.,
Brooklyn, N. Y.

HARRY P. STOW,
President and Manager,
Thomas Day Co.,
725 Mission St.,
San Francisco, Cal.

MOTOO UCHISAKA,
Sales Dept.,
Toyko Elec. Co.,
Kawasaki-Machi,
Managawa-Ken, Japan.

Eighteen Associate Members.

BENJAMIN PLATT ALLEN,
Factory Maintenance Man for Light and Power,
Whitlock Coil Pipe Co.,
Elmwood, Conn.

DENYSE WILLIAMSON ATWATER,
Illuminating Engineer,
Westinghouse Lamp Co.,
Bloomfield, N. J.

SUMNER E. BROWN,
Brown Reflector,
560 Fourth St.,
Boston, Mass.

JAMES E. BUCKLEY,
Agent, Bureau of Illuminating Eng.,
The New York Edison Co.,
130 E. 15th St.,
New York, N. Y.

MILO C. CAUGHREAN,
President,
Caughrean-Fedderson Corp.,
Ketchikan, Alaska.

P. D. CHAMBERLAIN,
Chamberlain Glass Co.,
318 2d Ave., South,
Seattle, Wash.

R. ROY COWLES,
Electrical Engineer,
Pacific Gas & Elec. Co.,
518 13th St.,
Oakland, Cal.

DAVID A. FEIGLEY,
Sales Mgr.,
Dillon Lens & Mfg. Co.,
Bridgeport, Ohio.

J. CARL FISHER,
Power Salesman,
Consolidated Gas, Elec. Light & Power Co.,
Baltimore, Md.

W. S. HERMANN,
Illuminating Sales Engineer,
Electrical Specialties Co.,
69 State St.,
Detroit, Mich.

PERRY E. HURD,
Illuminating Engineer,
Westinghouse Lamp Co.,
538 Widener Bldg.,
Philadelphia, Pa.

HERBERT H. KIMBALL,
Meteorologist,
U. S. Weather Bureau,
Washington, D. C.

CHESTER ARTHUR MUSSON,
Salesman,
United Elec. Lt. & Pwr. Co.,
2420 Broadway,
New York, N. Y.

FRANK H. RICHARDSON,
Editor and Author,
Moving Picture World,
516 Fifth Ave.,
New York, N. Y.

GEO. LE BAR RISHELL,
Electrical Engineer,
Novelty Incandescent Lamp Co.,
Emporium, Pa.

YOSHICHIRO SHIMIDZU,
Engineer,
Tokyo Electric Co.,
Kanagawaken,
Kawasaki, Japan.

G. WALTER SPENCER,
Spencer Electric Co.,
355 12th St.,
Oakland, Cal.

EDWARD L. TIFFANY,
Electrical Engineer,
United States Rubber Co.,
393 East Chapel St., Box 606,
New Haven, Conn.

OTHER CHANGES IN MEMBERSHIP.

Two Transfers to Member Grade.

WILLIAM PERCY DOBSON,
Laboratory Engineer,
Hydro Electric Power Commission of Ontario,
8 Strachan Ave.,
Toronto, Ontario, Canada.

TECHNICAL BULLETINS.

Past President Doane proposed some time ago that a series of technical bulletins be issued under the joint auspices of a proposed new committee on technical publicity and the Committee on Papers. These bulletins to be underwritten and purchased for distribution by sustaining members. The proposition recently has aroused considerable interest and is being very carefully considered.

COMMITTEE ACTIVITIES.

SKY BRIGHTNESS COMMITTEE.

ABSTRACT OF A CIRCULAR LETTER TO THE COMMITTEE ON SKY BRIGHTNESS, I. E. S., DATED AUGUST 25, 1920, AND SIGNED BY THE CHAIRMAN, H. H. KIMBALL, WEATHER BUREAU, WASHINGTON, D. C.

It is suggested that the following "Outline of Daylight Measurements," decided upon at a meeting of the Committee on May 8, 1919, be adopted as the starting point for the program for 1919-1920:

Outline of Daylight Measurements.

1. Normal solar illumination throughout perfectly clear day, at the same time securing sky brightness throughout arcs of great circles from north to south, east to west, making measurements as near the horizontal as practicable, and at zenith and several points in between. These readings should be accompanied by horizontal illumination values from the unclouded sky, both with and without the sun.

2. The ratio of vertical illumination to sky angle with the test plate facing the cardinal points of the compass. The sky angle should be varied from 90° to 15°, probably in 15° steps.

3. Measurements of horizontal illumination, together with a duplication of test 2, should be made on an overcast day. All measurements should be made at least from sunrise to noon, or from noon to sunset throughout at least one perfectly clear day and one evenly overcast day.

An expression is asked on the following points:

1. Does the above program adequately cover the field of sky brightness?

2. If not, what additional observations or investigations seem advisable?

3. Will you kindly indicate what part you can take in carrying out the program after modification as suggested by you.

Reference is made to a paper in the *Monthly Weather Review* for November, 1919,[1] which shows by means of tables and charts the intensity of solar illumination at normal incidence, and on vertical surfaces variously oriented, at different hours of the day, seasons of the year, and places in the United States. Similarly, there is also given the illumination on a horizontal surface from the sun and sky when the sun is unobscured by clouds, and from an overcast sky with the sun at different altitudes above the horizon.

It is asked if these data are presented in a form that is convenient for architects and others. If not, how should they be modified? Also, what additional data, in the forms of graphs or otherwise, are desired?

It is suggested that a digest of papers on Sky Brightness published in foreign languages should be prepared.

NEWS ITEMS.

The Society has been invited to become a charter member of the recently organized American Federation of Engineering Societies.

[1] A copy of this paper may be had upon application to the Chairman of the Committee.

PROFESSIONAL OPPORTUNITIES.

Note.—Beginning with Volume XV, No. 1, the General Office have been publishing details of business opportunities which have come to the office, with such success that it is now proposed to offer to our members, the facilities of this column under the heading of "Services Available." Advertisements sent in by members not exceeding fifty words will be printed without charge; such copy is not to be printed oftener than three issues per year for each member.

Young Men for Sales Department, with some business experience, and some technical education. Work will consist of course in Engineering Department at factory, covering brief apprentice course in testing and Engineering Department, especial emphasis being laid on illumination. This course will take a year or more and fit the candidate for outside sales work. Location New Jersey.

Z-1493

Sales Engineer for Illuminating Work wanted by large fixture manufacturer having standardized line. Capable aggressive salesman, well versed in general illuminating practice. Location, New York City. Salary $2400 to $3000.

Z-2078

Old Copies Transactions.

The General Office has temporarily discontinued the purchase of old copies of TRANSACTIONS previously advertised for.

SOCIETY OF MOTION PICTURE ENGINEERS INVITE MEMBERS OF THIS SOCIETY TO THEIR CONVENTION AT DAYTON, OHIO, OCTOBER 11th to 14th INCLUSIVE.

A telegram bearing this invitation was read at the Thursday morning session of the Convention in Cleveland.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Research and Industry—	Editorial	Aug. 1	104
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An Apparatus for Determining Acuity at Low Illuminations, for Testing the Light and Color Sense and for Detecting Small Errors in Refraction and in Their Correction—	C. E. Ferree and Gertrude Rand	Feb.	59
Journal of the Franklin Institute			
Purity of Palladium Used in Gold-Point Palladium-Point Brightness Ratio—	Edward P. Hyde and W. E. Forsythe	Aug.	257
Journal of the Optical Society of America			
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Eder-Hechts Graukeil-Photometer für Sensitometrie und Lichtmessung (Photogr. Korresp. 57, 1-9, 41-44, 1920)—	J. M. Eder	Vol. I, No. 8	502
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Die Grundlagen der Farbkunde und der Farbkunst (Chem.-Ztg. 43, 681-682, 1919)—	Wilh. Ostwald	Vol. I, No. 9	569
Uber Bogenlampen mit erhöhter Flächenhelligkeit (ZS. f. techn. Phys. I, 7-16, 37-47, 1920)—	Georg Gehlhoff	Vol. I, No. 10	630
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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XV NOVEMBER 20, 1920 No. 8

CONVENTION NOTES.

THE FOURTEENTH ANNUAL CONVENTION.

Those who were fortunate enough to be in Cleveland for the Convention are familiar with the excellent program of papers presented; those who, for one reason or another, were forced to forego the pleasures of so brilliant a gathering will find these considerations of their favorite subjects preserved for them in the published TRANSACTIONS. Many papers will appear in this issue and others in the December issue.

Those who were absent missed a program of entertainment so varied and unique that several of its features may never be duplicated.

The banquet was a history of lighting and civilization. Just as the Greek, the Roman, the Renaissance and other periods are the milestones which indicate the progress of man's mental enlightenment, so are the illuminants of these periods, from the Greek and Roman pottery lamps to the more modern candle. Few of the guests appreciated that the lamps used were either original or authentic copies removed from the Historical Museum at Nela Park for the occasion.

Speechmaking of the after-dinner variety was conspicuous by its absence. General Harries, as toastmaster on behalf of the Society, presented President Doane with a gold emblem of the Society as a token of appreciation and esteem for his past year's work as presiding officer, remarking as he did so that he was anticipating next year's banquet when he might profit by the custom he was starting. The General's witty remarks at the expense of some of the more prominent members were enjoyed equally by the members at whom they were directed and those who feared they might be the next target. A comprehensive vaudeville program followed and the evening's entertainment was completed with informal dancing.

The usual formal President's Reception and Dance was held on Monday evening. The dancing was delightfully informal and the introduction of several unusual favor dances was a decidedly attractive innovation. The popularity of the orchestra may be explained by mentioning the fact that they were veterans of the famous Naval Reserve Band.

On Tuesday evening, the National Lamp Works entertained with dinner and dancing at Nela Park. The paper on "Home Lighting" by Messrs. Hogue, Tillson and Kirk was presented to the members and guests immediately after the dinner, and during the evening, a number of interesting features were available, including a demonstration of home lighting, one of industrial lighting, a visit to the Historical Museum, a motion picture of the manufacture of mazda lamps and a trip to the glass works where bulbs and tubing are made.

The convention was a success in every way and the committees in charge are to be congratulated for the efficient work. A precedent has been set in both the papers and entertainment programs and in attendance.

OUR MILITARY PRESIDENT.

At the Joint Luncheon of the Cleveland Engineering Society, the Cleveland Electrical League and the Illuminating Engineering Society, on October 7th, retiring President Doane in presenting incoming President Harries spoke as follows:

"In laying down the duties of this office, I wish to express my appreciation of the support you have given me. You have given me considerable credit for what I trust you will agree, has been a rather successful year. Very much of the credit should go to those who will receive less mention. I presume it is always thus.

"I thank you all. I wish I could thank each one of you separately.

"Each year at the close of the Convention the outgoing president introduces his successor. In performing this duty it is my very great privilege to-day to introduce to you a man who has achieved distinction as an army officer, engineer, business executive and diplomat. Born in Wales he came to this country in the seventies and enlisted in the United States army, winning one promotion after another for fourteen consecutive years.

"During ten of these years he served west of the Missouri River, averaging more than one Indian campaign a year.

"He was colonel of a regiment in Cuba.

"He was seventeen years in command of the military and naval forces of the District of Columbia.

"When the war broke out, the General promptly offered his services and was sent abroad as a Brigadier General, in charge of a brigade which contained four companies of Cleveland troops.

"He wears in his lapel a ribbon bar indicating that he has been awarded the United States Distinguished Service Medal. General Pershing said in the citation which accompanied the medal, 'He overcame what appeared to be unsurmountable obstacles.'

"The French made him, while he was still a brigadier general, a commander of the Legion of Honor, the first time that this honor has been awarded any officer of lower rank than a major general.

"England, Russia, Italy, Serbia, Roumania, Montenegro, and others have each given him decorations and otherwise have done their best to pay your President every honor within their power. He saw the war from several angles. He went across as a combat officer but was almost immediately assigned to engineering and executive work.

"General Harries shortly after his arrival in France was assigned to develop the port at Brest and before the close of the war had four ports under his charge.

"The magnificent work done in developing this port at Brest is evidenced by the fact that before the close of the war this port was so developed that it had handled in one day 35,000 troops and their equipment. The Army Board had previously reported that the ultimate capacity of this port would be 20,000 troops and 6,000 tons of supplies per month. It was no small achievement to have so developed facilities that 50 per cent. more than the estimated

month's capacity could be handled in a single day. It was not to be wondered that General Pershing should have said, 'He overcame what appeared to be unsurmountable difficulties.'

"The General saw the war in the saddest way of all, for he gave his son, a lieutenant of Infantry who now lies buried in France.

"I take pleasure in introducing to you, your new President, Brigadier-General Geo. H. Harries."

In responding to the remarks passed by President Doane, General Harries said he was much indebted to his friend Doane for refraining from probing more deeply into his life. He said, "It was far from being complimentary because I could not help being in the army. Anyone who was properly insane went into the army and mine was congenital. I had exactly seven generations of soldiers in a direct line back of me. I couldn't help it. I was a hopeless and incurable case.

"You know, when I say insane, I say it advisedly because there are still a great many people in this country, in this Land of the Free and Home of the Brave, with some pacifistic discount on the 'brave' and a slight contraction of the 'freedom' (I hope your abbreviated freedom won't interfere with your New Year's celebration)—who wonder why any man is foolish enough to fight for his country. They don't comprehend. They deplore the fact that such people live and move and once in a while make a public appearance.

"We *are* curiosities. The man who thinks the land he lives in isn't worth defending, ought to be suppressed. I have some thoughts on that subject, but it will take more time than I have at my disposal to-day to express my views as to those who call themselves 'conscientious objectors'—and who may have been so in part."

President Harries' address is given on p. 504 of this issue.

ATTENDANCE PRIZE — 1920 CONVENTION.

Cleveland, Ohio,

Week of October 4-7, 1920.

About ten years ago, there was instituted the plan of presenting a prize to the Section of the Society which most loyally supported the Annual Convention by its attendance. This feature has always been an interesting one at the Annual Banquets, and this year proved no exception to the rule. The author of the idea, Mr. D. McFarlan Moore, made the presentation speech and introduced in a novel and interesting manner, thoughts that had to do with answering the question, "Who Are We?" together with a statement showing the number of delegates who were present from each of the Society Sections.

The prize was the traveling gavel, and it was awarded to the New England Section, but the final numerical figure which resulted in this decision was almost equaled by that of the Chicago Section. The percentage of the membership of a Section which was present at the Convention was either discounted or increased, by a per cent. which depended upon whether the distance traveled to the Convention city was greater or less than the average distance of the Section cities to the Convention city.

Mr. H. F. Wallace, Vice-President, of Boston as the representative of the New England Section, responded in a fitting manner after he was assured that the honor was well deserved.

Some of those in attendance this year came from both coasts of our country, and besides there were representatives from Canada.

All who had the great pleasure of attending the 1920 Convention of the Illuminating Engineering Society feel that—

When time which steals our years away,
  Shall steal our pleasures too,
The memory of the past will stay,
  And half our joys renew.

It was a success in every possible way, and perhaps much of the enjoyment was due to the fact that it was held in Cleveland, the 5th city, and in the State which will furnish the next President of the United States.

The Local Hospitality Committee of ladies, also did everything possible to make comfortable the stay of the visiting ladies, among whom was a bride.

Those in attendance at the Banquet made up a very distinguished company; some represented industries which if they ceased to exist, would throw the whole world into darkness, others were professors of great institutions of learning, or members of our Army, Navy or the Aviation branch of National Defense.

The Society succeeded in capturing for its next President a man whom the hordes of Germany were not able to capture.

A proof of the true worth of the Society, is the fact that there were present practically all of the ex-presidents with the exception of pioneer President Marks, who for the first time was unable to be present.

GONE BUT NOT FORGOTTEN.

It was the intention of the Convention Committee that a replica of tiny Roman lamps, cast in bronze, should be given the guests at the I. E. S. banquet in Cleveland as favors. The foundry man disappointed the committee and the bronze lamps did not arrive although there was a note in the program in reference to them.

The lamps actually used to light this banquet were originals of hundreds and in some cases thousands of years of antiquity and came from the Nela Park Museum. Two of these very small lamps disappeared at the banquet. Both were very old and hence the collection at Nela Park is short two of its choice specimens.

If anyone of the banqueters took these lamps under an impression given by the program that they were favors, they should return them to "Engineering Department Museum, Nela Park, Cleveland, Ohio."

SECTION ACTIVITIES.

CHICAGO.

A meeting of the Chicago Section was held on October 22, 1920, at 7:30 P. M. In the rooms of the Western Society of Engineers, Mr. J. R. Cravath presiding. General Harries gave an address on Society affairs.

The following topics have been chosen for future meetings, speakers to be announced in a later issue:

November—Joint meeting with the Electrical Contractors. Subject to be discussed, "How to Sell Industrial Lighting to Old Establishments."

December—Industrial Lighting Codes.

January—"Residence Lighting." A meeting with the Decorators, Architects, Lighting Men, Contractors, etc.

February—Meeting with Fixture Manufacturers and Dealers. "Selling

Good Lighting to the Public."
March—Inspection Trip to Lighting Installations.
April—"Train Lighting."
May—"Illumination and the Eye."

NEW YORK.

The October meeting of the New York Section greatly exceeded expectations. It was a joint meeting with the American Society of Safety Engineers and an unusually large number attended. There were eighty-five at the informal dinner and one hundred and seventy-five at the meeting, representation being about equally divided between the two Societies.

The remarks by past President Doane on "Elements of Good Lighting" were pertinent to the subject and carried an important message to our friends, the Safety Engineers. Mr. R. E. Simpson read an interesting paper on "Defective Illumination a Cause of Industrial Accidents." Mr. H. F. J. Porter representing the Society for Electrical Development read a very well written paper on "Reduction of Accidents Through Visual Acuity." This was followed by a moving picture film entitled "Through Life's Windows," which was most interesting, besides being instructive. The operation of the normal and subnormal eye was illustrated on the screen in a most striking manner. Mr. S. G. Hibben talked on "Industrial Lighting Equipment and its Maintenance" showing several charts, owing to its very practical value, this paper received the major part of the discussion. The meeting closed with a short descriptive paper on "Safety Disconnecting Hangers as a Safeguard," by A. J. Thompson.

Meeting—November, 1920.

The November 12th meeting of the New York Section was a record breaker both in attendance and enthusiasm. It was a joint meeting with the Electrical Supply Jobbers, held in the Auditorium of the New York Edison Co., 44 West 27th Street, New York City, where a permanent exhibit of Industrial Lighting has been installed to show the approved methods for the application of light. This is one of the exhibits planned by the Lighting Department of the National Electric Light Association for demonstrating various lighting systems and equipment, to promote educational propaganda on the necessity of good lighting. The effect of glare was demonstrated as well as the effect of varying intensities of lighting on the speed of vision.

Mr. Ward Harrison, Field Director, N. E. L. A., explained in a most comprehensive style the proper method of procedure in laying out a lighting system for industrial work. Foot-candle meters were placed on tables throughout the room and the light from the various systems was checked by those in attendance; thus the actual results of the conditions formed the basis of Mr. Harrison's lecture.

This novel feature by which the audience was enabled to take an active part created most favorable comment and the popularity of the meeting was evidenced by an attendance of over three hundred.

Meeting—December, 1920.

The December 9th meeting of the New York Section will be a joint meeting with the American Gas Association and will be held in the auditorium of the Consolidated Gas Company, 130 East 15th Street, New York City.

Dr. Howard Lyon will talk on the "Past, Present and Future of Gas Lighting."

Mr. R. H. Maurer will present data on "Tests of Gas Units."

There will be a very complete exhibition of Gas Lighting Units.

NEW ENGLAND.

The Board of Managers of the New England Section held a meeting on October 25th at which time Mr. L. T. Troland accepted the chairmanship of the Committee on Papers for the Section.

Arrangements were made for the first regular meeting of the season to be held December 3rd at the Engineers Club, Boston, Mass., at 8 P. M. Speakers will be Mr. J. C. Daniels on "Department Store Lighting," Mr. R. E. Simpson on "The High Cost of Poor Lighting." The next meeting of the Section will be held the latter part of January at which time it is hoped Mr. M. Luckiesh, Director of Applied Science at the Nela Laboratories, will talk.

PHILADELPHIA.

The opening meeting of the Philadelphia Section was held on November 19th at the Engineers' Club, 1317 Spruce Street, at 8:00 P. M. The paper of the evening entitled "The Knowns and Unknowns of Illuminating Principles" was prepared under the auspices of the Committee on Papers of the General Society, and was presented by the Committee Chairman, Mr. Preston S. Millar. A dinner at the Engineers' Club preceded the meeting and a buffet lunch was served afterwards.

SAN FRANCISCO BAY CITIES CHAPTER.

There was a joint meeting of the San Francisco Bay Cities Chapter with the San Francisco Electrical Development League on October 18th at the Palace Hotel, San Francisco, Cal., at 12:00 noon, the Chapter members being guests of the League. Mr. W. W. Hanscom was Chairman of the meeting and the attendance was 173.

Mr. Elmer Zimmerman of the Pacific States Electric Company, spoke on the subject, "Illumination and Production."

Mr. J. A. Vandergrift, of the National Lamp Works, discussed, "The Possibilities in Industrial and Commercial Illumination."

Both the addresses were illustrated with charts.

COUNCIL NOTES.

Upon the recommendation of the Board of Examiners, the following were elected to membership at the November 11th meeting of the Council:

Note—Names marked with asterisk elected prior to November 11th, 1920.

Five Members.

P. Y. DANLEY,
District Lighting Specialist,
Westinghouse Elec. & Mfg. Co.,
314 N. Broadway,
St. Louis, Mo.

FRED R. DIXON, JR.,
Supervisor Commercial Lt. Dept.,
Cons. Gas, Elec. Lt. & Pwr. Co.,
Lexington and Liberty Sts.,
Baltimore, Md.

EDWIN F. GUTH,
President and Gen. Mgr.,
St. Louis Brass Mfg. Co.,
2615 Washington Ave.,
St. Louis, Mo.

W. R. MCCOY,
Sales Mgr.,
Cassidy Co., Inc.,
15 Wilbur Ave.,
Long Island City, N. Y.

JOSEPH BERNARD WILSON,
Business Manager,
Massillon Gas & Electric Co.,
Massillon, Ohio.

Twenty-six Associate Members.

WALTER A. ALDEN,
Salesman,
Benjamin Elec. Mfg. Co.,
580 Howard St.,
San Francisco, Cal.

PAUL ANDERSON,
Research Work in Applied Optics,
R. R. No. 3,
Anderson, Mo.

S. A. BAKER,*
Macbeth Evans Glass Co.,
312 Rialto Bldg.,
San Francisco, Cal.

THOMAS E. BEATTY,
Electrical Engineer,
Oakland Mazda Lamp Div. of G. E. Co.,
1648 16th St.,
Oakland, Cal.

CHAS. RUSSELL BEHRINGER,
Engineer,
Mutual Box Board Co.,
Erie St.,
Utica, N. Y.

WILLIAM JAMES BOYD,
Manager,
Roberts Manufacturing Co.,
663 Mission St.,
San Francisco, Cal.

E. L. BRAGDON,
Editor,
Motion Picture News,
729 Seventh Ave.,
New York, N. Y.

D. C. BRICKWEDE,
Westinghouse Lamp Co.,
300 N. Broadway,
St. Louis, Mo.

HERBERT E. CAVE,
Vice-President and Gen. Mgr.,
Luminous Specialty Co.,
238 S. Meridian St.,
Indianapolis, Ind.

GEORGE R. CLARKE,
Illuminating Engineering Dept.,
National Lamp Works,
Nela Park,
Cleveland, Ohio.

R. ROY COWLES,*
Electrical Engineer,
Pacific Gas & Electric Co.,
518 Thirteenth St.,
Oakland, Cal.

LEROY C. DOANE,
Engineer,
Ivanhoe-Regent Works of G. E. Co.,
5716 Euclid Ave.,
Cleveland, Ohio.

K. FITZPATRICK, JR.,
Lighting Sales Agent,
Dayton Power & Light Co.,
50 S. Jefferson St.,
Dayton, Ohio.

PHIL C. KELLER,
Commercial Engineer,
Ivanhoe-Regent Works of G. E. Co.
5716 Euclid Ave.,
Cleveland, Ohio.

DOUGLASS JAMES KERR,
Lighting Fixture Salesman,
Roberts Mfg. Co.,
663 Mission St.,
San Francisco, Cal.

LOUIS F. LEUREY,
Consulting Elec. Eng.,
58 Sutter St.,
San Francisco, Cal.

WM. G. MARTHAI,
Illuminating Engineer,
New York Edison Co.,
130 E. 15th St.,
New York, N. Y.

W. C. MARTINEZ,*
Salesman,
Western Electric Co.,
300 Twelfth St.,
Oakland, Cal.

E. A. MILLS,*
Engineer,
The New York Edison Co.,
10 Irving Place,
New York, N. Y.

CLAUDE E. MOWRER,
Street Lighting Engineer,
The Detroit Edison Co.,
18 Washington Ave.,
Detroit, Mich.

EARL G. PERKINS,
Gen. Mgr.,
J. H. Wagenhorst & Co.,
704 Dollar Bank Bldg.,
Youngstown, Ohio.

CHARLES W. PRICE,
Editor and Publisher,
Electrical Review,
15 Park Row,
New York, N. Y.

M. F. SCHACHTER,
President,
Phenix Lighting Fixture Co.,
144 Bowery,
New York, N. Y.

J. L. WOLF,
Secretary,
Lighting Fixture Dealers Society of America,
Builders Exchange,
Cleveland, Ohio.

WILLIAM B. WOLFF,
Mgr. Lighting Dept.,
Electrical Construction Sales Co.,
934 Prospect Ave.,
Cleveland, Ohio.

E. ELLSWORTH WOOD,
Miniature Incandescent Lamp Corp.,
95 Eighth Ave.,
Newark, N. J.

Five Transfers to Member Grade.

EUGENE F. MCCARTHY,*
Illuminating Engineer,
Consultant in Colored Illumination,
120 Tremont St.,
Boston, Mass.

LOUIS D. MOORE,
Electrical Engineer,
Missouri Pacific Railroad Co.,
1130 Railway Exchange Bldg.,
St. Louis, Mo.

R. E. MYERS,
Chief Engineer,
Westinghouse Lamp Co.,
Bloomfield, N. J.

ELLIOTT REID,
Sales Manager,
Westinghouse Lamp Co.,
165 Broadway,
New York, N. Y.

T. G. WHALING,
General Manager & Director,
Westinghouse Lamp Co.,
165 Broadway,
New York, N. Y.

COMMITTEE ACTIVITIES.

SUGGESTIONS REQUESTED FOR REVISION OF STATEMENT ON KNOWN AND UNKNOWNS OF ILLUMINATING PRINCIPLES.

Under the auspices of the Committee on Papers, 36 mimeographed copies of this statement were distributed to members at the recent convention in Cleveland. From the persons receiving these copies criticisms designed to improve a revision of the statement are solicited. The help of every member in contributing toward a revision which will cause this statement correctly to reflect the present status of our knowledge of illuminating principles is needed.

NEWS ITEMS.

ABSTRACT OF ARTICLE ON "OPTICAL DETERMINATION OF STRESSES IN AIRPLANE SPARS."

(*The Journal of the Society of Automotive Engineers*, October, 1920.)

Engineering (London) refers to a recent meeting of the Royal Aeronautical Society at which Major A. R. Low

of the Royal Aircraft Factory described a series of experiments in determining the stresses on airplane spars by optical methods. The spars were reproduced to scale, making the wood parts of xylonite and the struts and bracing wires of steel. The stresses in the xylonite were then determined by the well-known method of observing the color effects produced by polarized light. The results were reduced to numerical values by finding the necessary tensional stress which must be applied to a corresponding piece to obtain the same color in the field of the instrument.

LIGHTING WEEK IN BUFFALO.

The Society will participate officially in the celebration of "Lighting Week" in Buffalo, N. Y., February 14th to 19th inclusive, I. E. S. activities being under the auspices of the following committee:

M. Luckiesh, Chairman
S. G. Hibben
A. L. Powell
W. T. Blackwell
R. H. Maurer

Mr. Herman Plaut, Chairman of the Membership Committee of the New York Section, plans an active campaign for new members during this period and in this connection will maintain a headquarters for the Membership Committee in Buffalo.

ORGANIZING A SECTION IN CLEVELAND.

The formation of a Section of this Society at Cleveland, Ohio, was authorized by the Council at the November meeting. The territory of the new section will take in a large part of northern Ohio, and it is understood that Mr. J. R. Colville has agreed to act as temporary chairman during the work of organization with E. duB. Stryker as Chairman of Membership Committee.

The Cleveland Section of the American Institute of Electrical Engineers extended to our embryo section in that city an invitation to its November 16th meeting at which Mr. C. A. B. Halvorson, Jr., Engineer, Lynn Works of General Electric Company, talked on "Searchlight Development."

FEDERATED AMERICAN ENGINEERING SOCIETIES.

Mr. Walter C. Allen was again appointed by the Council as our delegate (non-voting) to the meeting of The Federated American Engineering Societies, in Washington on November 18th and 19th.

PROFESSIONAL OPPORTUNITIES.

Note.—Beginning with Volume XV, No. 1, the General Office has been publishing a list of business opportunities which have come to the office. Under the heading of "Services Available," we offer to our members the facilities of this column. Advertisements sent in by members not exceeding fifty words will be printed without charge; such copy is not to be printed oftener than three issues per year for each member.

Physicist—who has had a doctor's degree from two to five years. Experienced in general and electron physics. High grade man wanted. Location New Jersey. Z-2167

Electrical Engineer—for physical testing of lamp materials and general test on lamps. Must be able to take charge of Laboratory. Graduate with two years experience. High grade man wanted. Location New Jersey. Z-2168

Physicist—experienced in light and sound to be in charge of laboratory for large industrial company in Connecticut—location Bridgeport. Z-2308

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

Electrical Record			
Efforts Toward Standardization in the Lighting Fixture Industry—Manufacturers are Striving for Fewer Designs and More Economical Production—		Sept.	165
Electrical Review (London)			
Light—Its Use and Abuse—		Aug. 20	249
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Cost Problems in the Lighting of Public Parks—	C. H. Shepherd	Sept. 11	389
Period Styles in Lighting Fixtures—	M. Luckiesh	Sept. 11	395
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Electrical World			
N. E. L. A. to Conduct Lighting Demonstrations Through New Department—		Sept. 11	545
The Real Meaning of Productive Illumination Intensities—	Davis H. Tuck	Oct. 2	684
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Photochemistry of visual purple—I. The kinetics of the decomposition of visual purple by light—	Selig Hecht	Sept.	1
Journal of the Washington Academy of Sciences			
Scientific Research — The economic importance of the scientific work of the Government—	E. B. Rosa	June 19	341
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Neon-Glimmlampen für Sparzwecke—		July 15	300
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Eine neue Karbidlampe—		July 15	309
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The Action of Ultra-Violet Light on the Yeast-like Fungi—(from J. Ind. Eng. Chem., 1920, p. 740)—	B. Feuer and F. W. Tanner	Sept.	269

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TRANSACTIONS
OF THE
Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

/23

VOL. XV DECEMBER 30, 1920 No. 9

SECTION ACTIVITIES.

CHICAGO.

Meeting—November, 1920.

The monthly meeting of the Chicago Section was held on Nov. 19th, at 7:30 P. M. in the Western Society Rooms, Monadnock Building. Mr. J. L. Stair presided.

The paper of the evening entitled "The Why and How of Co-operation Between the Electrical Contractor and the Illuminating Engineer" was presented by Mr. J. W. Collins.

The following topics have been chosen for future meetings, speakers to be announced in a later issue:

December—Industrial Lighting Codes.
January—"Residence Lighting." A meeting with the Decorators, Architects, Lighting Men, Contractors, etc.
February—Meeting with Fixture Manufacturers and Dealers. "Selling Good Lighting to the Public."
March—Inspection Trip to Lighting Installations.
April—"Train Lighting."
May—"Illumination and the Eye."

NEW YORK.

Meeting—December, 1920.

The December 9th meeting of the New York Section was held in the Auditorium of the Consolidated Gas Co., New York City, and was of particular interest as the papers of the evening were on the subject of Gas. Dr. Howard Lyon of the Welsbach Co. gave a very interesting and instructive talk on "Gas Lighting, Past, Present and Future." He explained the composition of various kinds of illuminating gas, their operations and effect upon the delicate structure of the gas mantle. He described in detail the manufacture of the mantle and touched upon the extensive research pursued, with particular emphasis on cleanliness of materials and purity of atmosphere required to secure the best product.

Mr. R. H. Maurer of the Consolidated Gas Co. presented a paper on the "Testing of Gas Lamps" and pointed out the differences between this method and the method for testing electric incandescent lamps.

A most complete and attractive exhibit had been installed by Mr. F. R. Barnitz, Assistant Secretary of the Consolidated Gas Co. It consisted of a booth in the form of a large show window containing side wall and ceiling fixtures of various types equipped with vertical and inverted gas mantles as required. On either side were printed in gold letters I. E. S. Supplementing this were smaller booths, one on each side, in which were displayed the new semi-indirect gas units. Gas floor lamps were placed at either side of the stage and also at the rear of the hall. It made a very attractive setting for the meeting. About one hundred and fifty people attended.

Meeting—January, 1921.

The January 13th meeting of the New York Section will be held in the Engineering Societies Building, 29 West 39th Street, New York City. This will be a joint meeting as invitations are to be extended to the Metropolitan Contractor Dealers and the Fixture Manufacturer Dealers. The subject of the evening will be "Commercial Fixtures."

The following papers are proposed:

"What the Idea is" by O. H. Caldwell.

"Its Relation to Better Lighting" by M. Luckiesh.

"The Fixture Man's Viewpoint" by W. R. M'Coy.

"How it Affects the Contractor Dealer" by W. J. Shore.

NEW ENGLAND.

Meeting—December, 1920.

The December meeting of the New England Section was held at the Engineers Club on Friday evening, Dec. 3rd, at 8 P. M., with Mr. N. W. Gifford, the newly elected chairman, presiding. Mr. Gifford announced that Mr. H. F. Wallace, Vice-President of the Section, had brought to Boston from the Fourteenth Annual Convention of the Society the rosewood gavel won by the New England Section for the largest attendance in the point of miles traveled. He called the attention of those in attendance to the importance of a full discussion of the papers to be presented and his remarks evidently had the desired results.

Mr. Julius Daniels presented his paper entitled, "Department Store Lighting."

Mr. R. E. Simpson presented a paper entitled, "The High Cost of Poor Lighting." Each of these papers was discussed by at least a dozen persons.

The next meeting of the Section will be held the latter part of January at which time it is hoped Mr. M. Luckiesh, Director of Applied Science at the Nela Laboratories, will talk.

NEW CLEVELAND SECTION.

An organization meeting was scheduled to be held on Dec. 20th, to decide what manner of organization the local members feel is desirable for Cleveland. Permanent officers for the coming year were to be elected at that meeting, an account of which will be given in the next issue of the TRANSACTIONS.

SAN FRANCISCO BAY CITIES CHAPTER.

The California Electrical Co-operative Campaign Committee has extended an invitation to members of the San Francisco Bay Cities Chapter to furnish speakers and demonstrations for the Industrial and Commercial Lighting Exhibit which has been installed in the Safety Museum of the Industrial Accident Commission. Meetings are to be held every Friday evening as long as interest can be maintained in this exhibit. The Board of Managers of the San Francisco Bay Cities Chapter will meet shortly to arrange the allotment of speakers who will in each case be introduced at the exhibit as members of the San Francisco Bay Cities Chapter.

The following officers have been elected for the year 1920-1921:

Chairman—L. E. Voyer.

Secretary—H. H. Millar.

Treasurer—J. A. Vandegrift.

Board of Managers—

W. W. Hanscom
R. H. Hudson
Romaine Myers
R. S. Prussia
Miles F. Steel

COUNCIL NOTES.

Upon the recommendation of the Board of Examiners, the following were elected to membership at the meeting of the Council on Dec. 9th:

One Sustaining Member

KRISTIANIA ELEKTRICITETSVERK,
Kristiania, Norway.

One Member.

M. J. CLEARY,
District Manager,
Benjamin Electric Mfg. Co.,
314 Victoria Bldg.,
St. Louis, Mo.

Seven Associate Members.

FRED E. BURDEN,
Quality Engineer,
Novelty Incandescent Lamp Co.,
St. Marys, Pa.

CARL COHEN,
Commercial Engineer,
Chas. Atkins & Co. (W. A.), Ltd.,
Perth, Western Australia.

C. G. EICHELBERGER,
Commercial Engineer,
Union Gas & Electric Co.,
4th and Plum Sts.,
Cleveland, Ohio.

EUGENE M. FISK,
Engineering Assistant,
Western Union Telegraph Co.,
195 Broadway,
New York, N. Y.

CLAUD M. HALL,
Optometrist,
210-11 Insurance Bldg.,
Glens Falls, N. Y.

JOHN W. C. PRICE,
Lighting Specialist,
Western Electric Co., Inc.,
151 Fifth Ave.,
New York, N. Y.

W. H. MORREAU,
The Morreau Co.,
1303 Oregon Ave.,
Cleveland, Ohio.
(Subject to the approval of the Board of Managers.)

Three Associate Members.

ROBERT WHITNEY JORDAN,
Electrical Engineer,
Edison Lamp Works,
Harrison, N. J.

BEN H. KREY,
Electrical Engineer,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

LORNE K. LLOYD,
Illuminating Specialist,
Mitchell Holland Co., Ltd.,
589 St. Catherine St.,
Montreal, Quebec, Canada.

COMMITTEE ACTIVITIES.

SUGGESTIONS REQUESTED FOR REVISION OF STATEMENT ON KNOWNS AND UNKNOWNS OF ILLUMINATING PRINCIPLES.

Under the auspices of the Committee on Papers, 36 mimeographed copies of this statement were distributed to members at the recent convention in Cleveland. From the persons receiving these copies criticisms designed to improve a revision of the statement are solicited. The help of every member in contributing toward a revision which will cause this statement correctly to reflect the present status of our knowledge of illuminating principles is needed.

COMMITTEE ON EDUCATION.

Prof. W. J. Drisko, of the Massachusetts Institute of Technology, has been

appointed to succeed Prof. C. F. Scott as Chairman of the Sub-Committee on Colleges and Technical Schools. Prof. Drisko has been connected for some time with the Department of Physics at the Massachusetts Institute of Technology, but this year has been assigned in particular to the development of the work on illuminating engineering and is perhaps more definitely a professor in illuminating engineering than any one else in the country.

Mr. S. G. Hibben of the Westinghouse Lamp Company, Bloomfield, N. J., has been appointed successor to Mr. F. A. Grohsmeyer as Chairman of the Sub-Committee on Popular Education.

The Sub-Committee on Extension Work consists of:

Mr. F. A. Vaughn, Chairman.
Prof. F. A. Kartak, Milwaukee School of Engineering.
Mr. F. A. Delay, Mechanical Appliance Co., Milwaukee.
Dr. Nelson M. Black, Well Building, Milwaukee.

The Committee on Education has been conducting a very interesting comparative test and public demonstration of lighting units in connection with an extensive program for the lighting of all the public school buildings of Columbus. Sixteen different units were represented.

COMMITTEE ON SKY BRIGHTNESS.

Mr. H. H. Kimball, Chairman of the Committee on Sky Brightness, at the meeting of the Council on Dec. 9th, stated that the schedule for the year contemplates the development of a practical program of observations for selected stations, and the preparation of a summary of data already available. At the same time, attention is being given to new forms of recording apparatus that are being developed for the purpose of recording daylight illumination.

COMMITTEE ON PAPERS.

At the Council meeting on Dec. 9th, Mr. P. S. Millar, Chairman of the Committee on Papers, reported a fairly well established consensus available to show the views of the members of the committee as to a desirable distribution of TRANSACTIONS material on the various phases of the subjects within the Society's purview. This table is given below:

CONSENSUS OF MEMBERS OF 1920-1921 COMMITTEE ON PAPERS AS TO DESIRABLE DISTRIBUTION OF TRANSACTION MATERIAL.

Underlying arts and sciences		17%
Architecture	2%	
Decoration	2	
Light production	2	
Physics (including optics)	4	
Physiology	5	
Psychology	2	
Materials of illumination		13%
Accessories	4%	
Fixtures	4	
Illuminants	4	
Surface coatings	1	
Elements of lighting principles		18%
Brightness	4%	
Color	3	
Glare	6	
Intensity	5	
Lighting practice		33%
Daylight	3%	
Economics	3	
Exterior lighting	4	
Interior lighting	11	
Projection	4	
Safety	3	
Sign lighting	3	
Signal	2	
Specialties		16%
Illuminating engineering	8%	
Photometry	5	
Units, standards and nomenclature	3	
Miscellaneous		3%

COMMITTEE ON MEMBERSHIP.

The Committee on Membership is planning to have a Membership Campaign at the Buffalo Convention of the Council of Lighting Fixture Manufacturers, Glass Guild and Fixture Dealers Society of America, superintended by Mr. H. Plaut, Chairman of the New York Section Membership. Mr. Plaut is arranging for the following:

A booth with literature, in charge of an I. E. S. member who can explain the aims and usefulness of the I. E. S. and its relation to the industries represented at the Convention.

A daily address by a representative of the I. E. S. before the general convention.

An address by a member of the I. E. S. before the individual meetings of the three groups represented at Buffalo.

All addresses are to be principally confined to the advantages of membership in the I. E. S.

NEWS ITEMS.

FAREWELL LUNCHEON TO MR. CRAVATH.

On Nov. 29th nineteen members of the Chicago Section, I. E. S., gave a luncheon at the Hamilton Club, Chicago, to James R. Cravath, who is leaving soon to take up his permanent residence in California. Short addresses were made by each one present which touched on the very active and valuable services of Mr. Cravath to the Society of which he is a charter and continuously loyal member. One of the speakers commented on Mr. Cravath's unusually generous act in closing up his home and business in order that he might improve the health of a member of his family. The best wishes of all present were extended to him.

OFFICER OF JAPANESE ILLUMINATING ENGINEERING SOCIETY ON ENGINEERING MISSION IN THIS COUNTRY.

Mr. Yutaka Fukuda, one of the founders of the Japanese Illuminating Engineering Society, and one of the active officers of the present administration, is visiting this country on an engineering mission. Mr. Fukuda is chief engineer of the Nippon Suioyoku Denki Kambushiki Kaisha (Nippon Hydro-Electric Power Co., Ltd.).

MR. NICHOLS TO ESTABLISH A MILITARY HOSPITAL.

Mr. G. B. Nichols who resigned in April last as Chief Engineer for New York State to enter the employ of the duPont de Nemours Company, Engineering Department, Wilmington, Del., has been granted a leave of absence by this company to take charge of preparing plans and building a hospital for the Federal Government for insane soldiers, at Jamaica, N. Y., under the New York State Commission for Military Hospitals. The hospital will have a capacity of 1,000 beds. Up to the time of his resignation from the State Department, Mr. Nichols was local representative of the Society in Albany. Mr. Nichols' present address is: Hall of Records Building, Dept. of Architecture, New York City, N. Y.

ILLUMINATION INDEX.

Prepared by the Committee on Progress

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

		DATE	PAGE
American Journal of Opthalmology		1920	
An Apparatus for Testing Light and Color Sense—	C. E. Ferree and G. Rand	Nov.	812
American Journal of Physiological Optics			
Refraction and Visual Acuity of the Human Eye—	J. P. C. Southall	Oct.	277
The Enigma of Color Vision—	L. P. Troland	Oct.	317
Central Station			
Studies in the Economics of Lighting—	E. L. Elliott	Nov.	128
Electrical Record			
Electrical Temperature-Measuring and Control Equipment—I.—		Nov.	322
Electrical World			
Psychology in Theater Lighting—	Editorial	Oct. 16	766
Lighting the World's Largest Theater—		Oct. 16	777
The Oregon Industrial Lighting Code—	Editorial	Oct. 23	815
Modern Industrial Lighting for Oregon—	F. H. Murphy	Oct. 23	820
Daylight Saving and Its Drawbacks—	Editorial	Oct. 30	861
Demonstrating Effective Lighting—		Oct. 30	865
Graphical Calculation of Illumination—	K. S. Weaver	Oct. 30	880
Industrial Lighting Fixture Which May be Raised, Lowered or Detached—		Oct. 30	884
Illumination for the Average Eye—	Editorial	Nov. 6	910
Color-Toned Incandescent Lamps—	Editorial	Nov. 20	1006
Electrician			
A New Mercury Vapor Lamp—		Oct. 1	383
Research and Research Workers—		Oct. 1	387
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Street Lighting Improvements in London—		Oct. 22	478
Elektrotechnische Zeitschrift			
Brennweitentoleranzen bei Scheinwerfer-Parabolspiegeln (L'Industrie Electrique, Bd. 29, 1920, S. 115)—		Sept. 2	696

Factory			
What One Plant has Learned about Lighting—		Nov. 1	1413
Gas Journal			
English Factories and Workshops Report (including Lighting)—		Oct. 20	141
Gas for Lighting in Housing Schemes—	H. Bloor	Oct. 27	206
General Electric Review			
The Cooper Hewitt Lamp—Part II. Development and Application—	L. J. Buttolph	Oct.	858
Helios			
Practical Illuminating Members for Confined Spaces—		Sept. 5	3266
Jahrbuch der Radioaktivität und Elektronik			
Uber das Emissionsvermögen der Metalle und die Methoden zu dessen Bestimmung—	F. Henning	Sept. 21	30
Journal de Physique et le Radium			
Photometre universel sans ecran diffusant—	H. Buisson et Ch. Fabry	Jan.-July	25
La possibilite de l'interpretation de la photophorese comme effet radiometrique (ZS. f. Phys., 1, p. 256, 1920)—	W. H. Westphal	Aug.	41
La destruction de la phosphorescence par les rayons positifs (ZS. f. Phys., 1, p. 42, 1920)—	Berndt	Aug.	42
Journal of Electricity			
Industrial Illumination—	J. J. McLaughlin	Nov. 1	418
Novelties in Lighting—	M. Luckiesh	Nov. 1	420
Tennis at Night—	L. E. Voyer	Nov. 1	414
Journal of the Franklin Institute			
Optical Glass and Its Future as an American Industry—	Arthur L. Day	Oct.	453
U. S. Army Searchlights—	Chester Lichtenberg	Oct.	509
The Annealing of Glass—	L. H. Adams and E. D. Williamson	Nov.	597
Journal of the Optical Society of America			
On the Relation Between Photographic Density, Light Intensity, and Exposure Time—	Frank E. Ross	Sept.	255
1919 Report of Standards Committee on Pyrometry—	W. F. Forsythe, Chairman	Sept.	305

Die Farbenplatte und das Farbensehen (aus Photogr. Rundschau, 1920, 169-180)—	Thiem	I, No. 17	1112
Die Psychologische Erklarung der Scheinbaren Gestalt des Himmelsgewolbes (Die Naturwissenschaften, 7, 937, 1919)—	Fritz Zweifel	I, No. 17	1114
Wirkungen des Lichts bei den toxischen Amblyopien (S.-A. ZS. f. Augenheilkunde 43, p. 73, 1920)—	Fritz Schanz	I, No. 17	1115
On the Effective Temperature of the Sun (Proc. Amsterdam, 22, p. 89, 1919)—		I, No. 17	1117
Power Plant Engineering			
Lighting of Power Houses—	A. D. Bell	Sept. 15	685
Proceedings Physical Society of London			
The Radiation from a Perfectly Diffusing Circular Disc—	John W. T. Walsh	Aug. 15	315
Psychological Review			
The Limits of Color Sensitivity: Effect of Brightness of Preëxposure and Surrounding Field—	C. E. Ferree and Gertrude Rand	Sept.	377
Science			
The Research Spirit in Everyday Life of the Average Man—	John C. Merriam	Nov. 19	473
Scientific American Monthly			
The Cost of Darkness—		Nov.	195
Sibley Journal of Engineering			
Mazda Lamps, Theory and Characteristics—	Henry Schroeder	Aug.	109
The Technical Review			
Utilization of Infra-Red Rays in Photography and Photometry (La Technique Moderne, Mar., 1920)—		Sept. 28	789

PAPERS ON LIGHT AND THE EYE.

The following papers relative to the effect of light upon the eye have been printed in the TRANSACTIONS of the Illuminating Engineering Society:

	YEAR	PAGE
"Matters of Illumination Which Affect the Eye," by Dr. Wendell Reber	1907	124
"Effects of Light Upon the Eye," by Dr. H. H. Seabrook	1908	156
"Eyesight and Artificial Illumination," by John T. Krall, M. D.		212
"Artificial Illumination from a Physiological Point of View," by Dr. Myles Standish		254

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XV | FEBRUARY 10, 1920 | No. 1

MILITARY SEARCHLIGHTS.*

BY CHESTER LICHTENBERG, CAPTAIN OF ENGINEERS
U. S. ARMY

Foreword.—Searchlights have been used for military purposes for over fifty years. They are essentially war materiel although in recent years they are being used for special illumination work. Their military application has been varied according to the strategy employed and the tactics involved. Their development has been spasmodic resulting from immediate needs in war times with practically no peace time demands. Their testing has been difficult owing to the many independent variables and the large parameters involved.

The startling events of the past four years have caused marked changes in military affairs and required fundamental and radical alterations in many lines of equipment. Searchlights are included in that class of materiel which experienced undreamed modification. They received a design and application impetus during the past two years which has more than counterbalanced the relative inactivity of the preceding fifteen years.

Service.—Searchlights are used by military organizations for detecting and illuminating distant targets. The visible area, color contrast, shape and relative speed of the targets varies through wide limits. They may be grouped in classes as follows:

1. *Buildings*, intrenchments, bodies of troops, and similar large stationary or essentially stationary targets on land.
2. *Automobiles*, motorcycles, bicyclists, horsemen, small bodies of troops, and similar agile and fast moving targets on land.
3. *Battleships*, troop ships, and similar slow moving targets on water.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to [illegible], 1919, Chicago, Ill.

4. *Destroyers,* motorboats, rowboats, and similar small, agile or fast moving targets on water.
5. *Bombers,* and similar cargo carrying and sluggish targets in air.
6. *Scouts* and similar fast agile targets in air.

The service requirements determine in a large measure the desirable characteristics of the most suitable searchlight. Distant targets require beams of great penetrating power, hence a beam of minimum divergence is sought. Near targets require beams of relatively great area covering power, hence a beam of maximum divergence is preferred. Fast moving targets demand an agile control of great responsivity. They require a beam of relatively wide divergence for their continued illumination. Slow moving targets may use a beam of relatively small divergence if the beam fully covers them at the nearest range to which they will be permitted to approach. So for each kind of target there is a beam which will best detect and illuminate it.

1917.—The year 1917 found the nations of the world confronted with at least one new problem. The science of aeronautics had developed with astonishing rapidity. High speed airplanes of huge carrying capacity were sent hundreds of miles under cover of darkness distributing terrifying and death dealing missles throughout wide areas. The destruction of life was serious. The undermining of the morale of the civil and military population threatened defeat.

The tactics were new. No counter efforts were known. Means for detecting the raiders were demanded. Searchlights were suggested, tried and found effective. The available materiel was, however, ill adapted for aerial service. It had been designed for detecting and illuminating land and water targets. The elevation range was limited to about 30°. The designs were heavy and immoble, being intended for installation in fixed fortifications. The control was sluggish being intended for following relatively large and slow moving targets on the earth's surface.

Survey.—A survey of the situation was ordered by Major General Wm. M. Black, the Chief of Engineers, United States Army in the early fall of 1917. It was inaugurated by Colonel R. S. A. Dougherty, Engineers. The investigation covered existing European practice and the probable trend of the art.

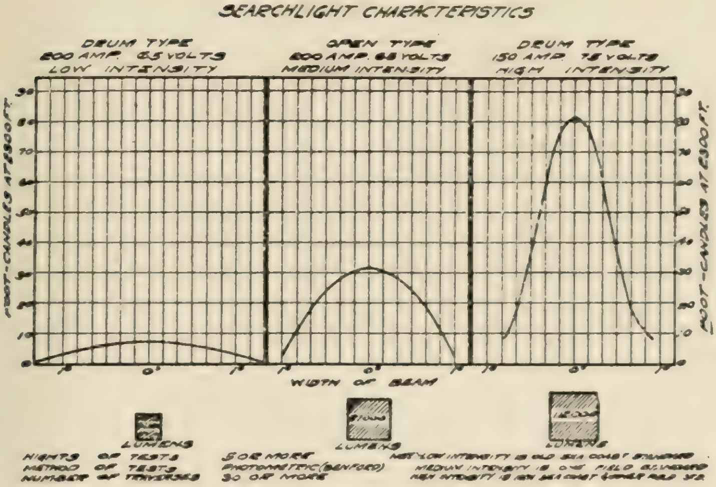

Fig. 1.—Beam illumination of 60 in. low intensity, medium intensity, and high intensity searchlights, photometrically determined at 2300 ft. range.

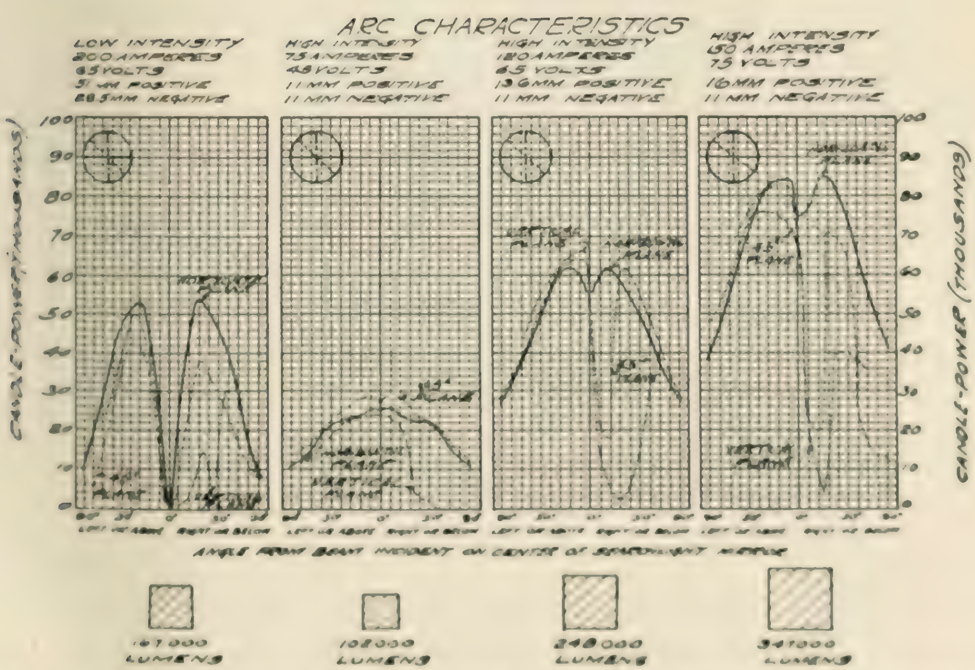

Fig. 2.—Arc illumination of low intensity and high intensity searchlight arcs, determined in three planes at 6 ft. range.

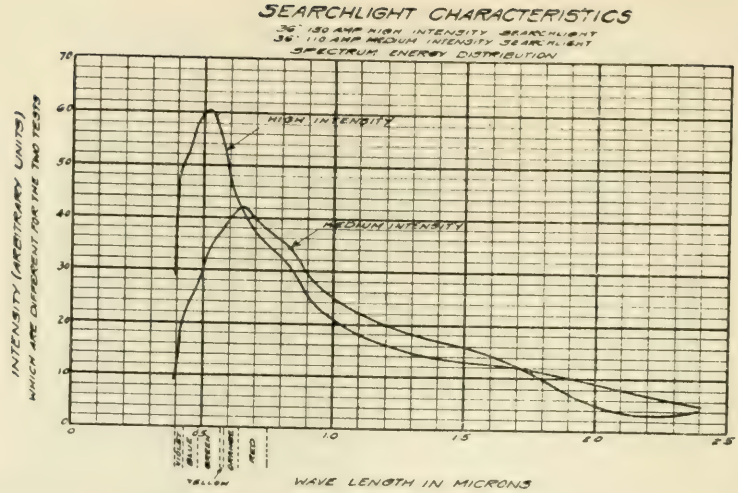

Fig. 3.—Spectrum energy distribution of medium intensity and high intensity searchlight arcs, bolometrically determined.

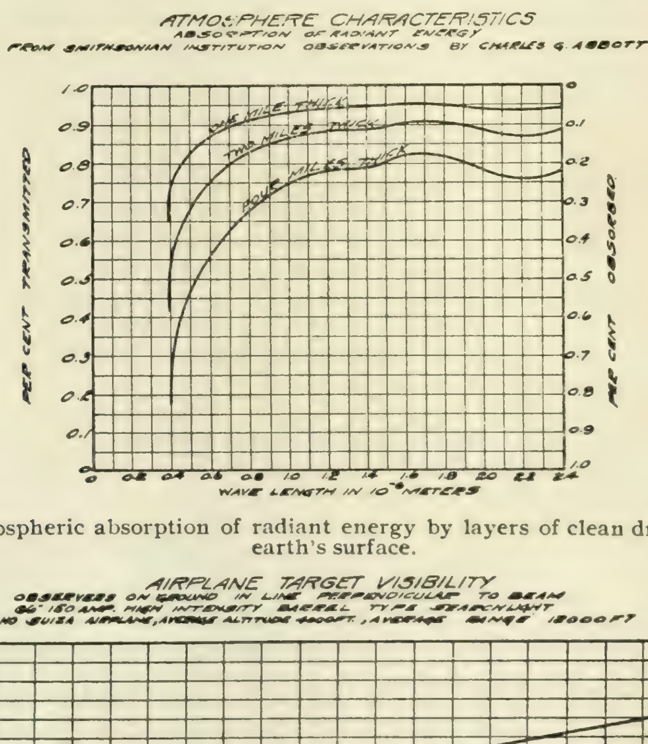

Fig. 4.—Atmospheric absorption of radiant energy by layers of clean dry air near the earth's surface.

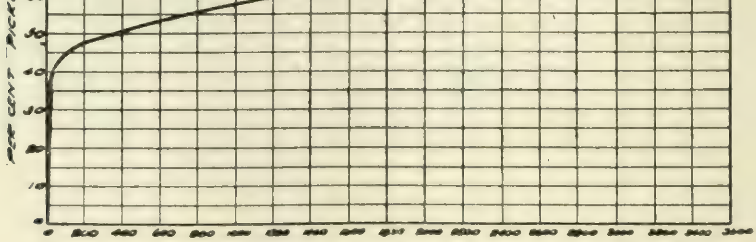

Fig. 8.—Relation between position of observer and his observing ability with relation to targets in air.

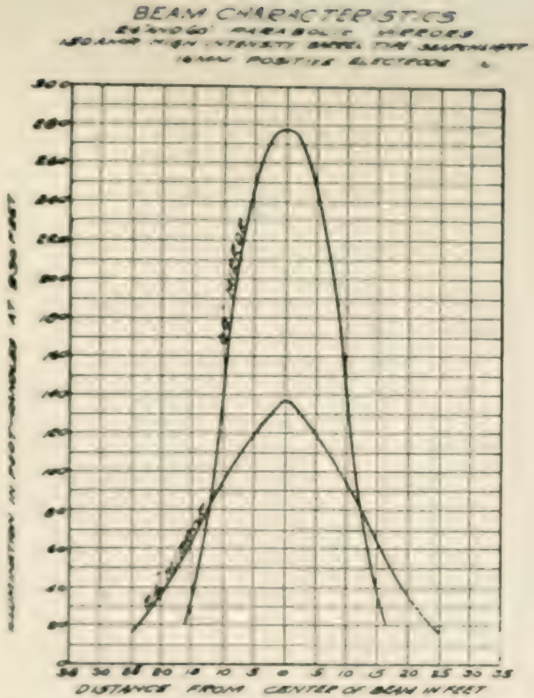

Fig. 5.—Beam illumination of 150 amp. high intensity searchlight arcs with 24 in. and 60 in. parabolic glass mirrors having 10 in. and 25-19/32 in. focal lengths respectively, photometrically determined at 930 ft. range.

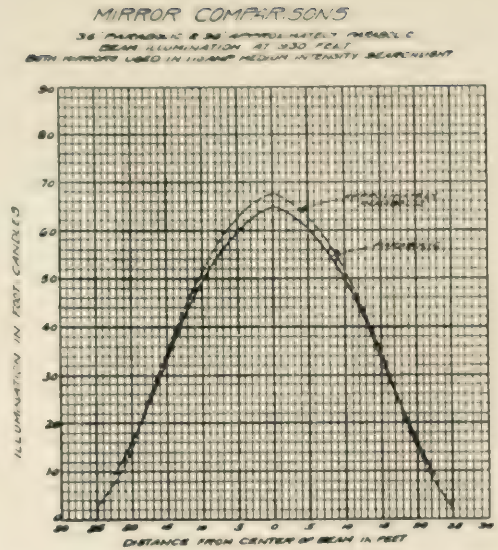

Fig. 6.—Beam illumination of 110 amp. medium intensity searchlight arcs with parabolic and approximately parabolic glass mirrors, 36 in. diameter, 14¾ in. focal length, photometrically determined at 930 ft. range.

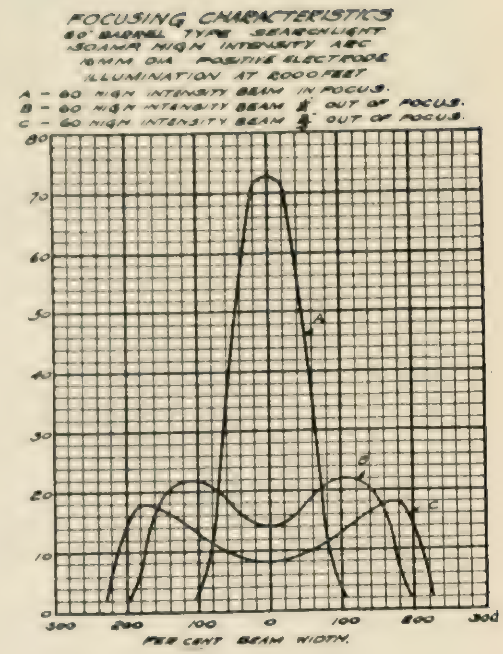

Fig. 7.—Effect on beam illumination of 150 amp. high intensity searchlight arc in 60 in. diameter, 25-19/32 in. focal length, when positive crater moved ½ in. and then ¾ in. out of focus.

It was found that the targets were new. They moved *above* the earth's surface at altitudes up to 25,000 ft. They were remarkably fast and agile. They were colored so as to blend with the backgrounds that they used. They moved singly or in formations. They were accompanied at times by screen or decoy units. They presented relatively small visible areas making detection at a distance difficult, even by daylight.

Problems.—The problems disclosed were many and difficult. Searchlights to meet the situation seemed to require new characteristics. They must have a relatively wide field to rapidly search a given area of sky. They should have a beam of good and well distributed illumination effective at ranges from 5,000 to 25,000 ft. Their design must be simple yet rugged since only inexperienced operating personnel would be available. They must be relatively light in weight to permit rapid movement from point to point. They must be relatively small in size to permit convenient intrenching. They must have reliable, silent and mobile power units which must not only carry the searchlights and personnel, but must furnish the power to operate the searchlights. The control must be simple, capable of operating the searchlights very fast for changing direction of search and relatively slowly for searching. It must permit searching through 240° in elevation and indefinitely in azimuth.

The requirements were new. The existing facilities limited to a few standard barrel searchlights each week. Thousands of units were needed immediately. Increasing production of developed designs was difficult because of the acute labor shortage. It was, therefore, imperative that new design and manufacturing facilities be sought and developed.

Mobilization.—Mobilization of existing resources was started in the spring of 1918. The principal manufacturers of searchlights and searchlight equipment were approached. The problems were presented to them. They were induced to assign new groups of engineers, designers and mechanics to the task. The aid of prominent scientists was enlisted and fundamental problems presented to them for solution. Close liaison was established with the American Expeditionary Forces in France. Advantage was taken of the facilities of the National Research Council to maintain contact with established scientific organizations of the Allied

nations. Every source of information or assistance was probed and advantage taken of each bit of data obtained.

Determinations.—The determination of the characteristics of existing searchlights and searchlight equipment was the next step taken. Existing methods were investigated. They were found to be antiquated and inaccurate. Expert assistance was sought. Dr. C. G. Abbott of the Smithsonian Institute, Messrs. I. G. Priest, E. C. Crittenden and A. H. Taylor of the Bureau of Standards, Physicist Enoch Karrer of the Army Engineers, Messrs. W. D'A. Ryan and F. A. Benford of the General Electric Company, and Mr. Preston R. Bassett of the Sperry Gyroscope Company were consulted. In co-operation with the Officer in Charge, Searchlight Investigations, United States Army, they surveyed the field, analyzed the problems involved, and developed and applied new and novel methods of determining the characteristics of searchlights for land, water and air service.

Beam Illumination.—Beam illumination was one of the first characteristics studied. Three methods of test were used. They were Abbott's, using a physical photometer, Karrer's, using portable photometers, and Ryan and Benford's, using a fixed photometer.

Dr. Abbott's physical photometer consisted essentially of a Coblentz radiometer cell placed at the focus of a parabolic mirror and connected with a galvanometer. The cell produced an electromotive force directly proportional to the light energy which impinged upon it in wave length proportion as the human eye would be affected. A number of these photometers were located at equidistant points across a diameter of the beam to be investigated. They were carefully calibrated, and observations with each taken successively. The procedure was simple. The readings were rapidly obtained. The results were accurate. They did not depend on the sensitivity of the human eye and were not marred by atmospheric changes. They permitted an illumination curve across a searchlight beam to be taken in about five minutes.

Messrs. Karrer, Ryan and Benford used standard photometers placed in and directed at the beam from the point where the illumination measurement was desired. Mr. Karrer held the beam fixed in position and moved the photometers across a horizontal diameter. He directed a portion of the vertical diameter

of the beam into a fixed photometer by means of a vertically movable white plate. Messrs. Ryan and Benford maintained the photometer fixed in position and moved the beam horizontally and vertically across a fixed scale, the photometer fixed at the center of the scale. Mr. Karrer's scheme enabled an early start to be made in the determinations when time was all important. Messrs. Ryan and Benford's scheme required a bit more preparation. Both produced excellent results which were extremely helpful in making searchlight investigations.

Messrs. Ryan and Benford are now developing a scheme for photometering a beam from a distant point such as an observer's station. They employ a system of lenses, as in a telescope, in combination with a photometer.

Arc Illumination.—Arc illumination is the basis for all searchlight calculations. The amount of light energy available, and its distribution are vital factors in projecting beams. Methods for determining the characteristics of arcs and other similar sources of light used in searchlights were developed by Messrs. Crittenden, Karrer and Benford.

Messrs. Crittenden and Karrer determined arc illumination by the use of mirrors and a photometer. The arc and photometer were held fixed in position. The mirrors were rotated around the arc step by step in three great circles. Photometric observations were made at each step. The observations were plotted and a characteristic curve obtained. The curves gave direct means for comparing the various arcs and other light sources used or considered for searchlight.

Mr. Benford used a hollow hemisphere with its concave side receiving and collecting the light. A reflecting surface at the focus and a photometer located outside the hemisphere complete the equipment. The observations give the total light from the arc or the beam when a mirror is placed behind the arc.

Spectrum Energy.—Spectrum energy characteristics of sources of light for searchlights are of prime importance. Their form gives the distribution of the light energy in the source. The maximum point gives a clew to the temperature of the source. Their study reveals the efficiency and usefulness of the source.

Dr. Charles G. Abbott of the Smithsonian Institute made careful determinations of the spectrum energy distribution of the

beams of medium and high intensity arcs. He applied methods which he had developed and found successful in studying the sun. The temperature of medium intensity arcs was found to be about 3,500° C. abs. The temperature of high intensity arcs was found to be about 4,500° C. abs. The beams of medium intensity arcs were found to have large amounts in the yellow and orange with a maximum at 0.65 micron. The high intensity arcs were found to have large amounts in the green with a maximum at 0.52 micron. The high intensity arcs also gave a characteristic strikingly similar to that of the sun beyond the earth's atmosphere. The high intensity arcs were also found to be more efficient than the medium intensity arcs. For the same energy the high intensity arcs produced over one-third more light than the medium intensity arcs. This is shown clearly by the spectrum energy characteristic. The medium intensity arc plotted has considerably more energy in the red and infra red than the high intensity arc even though the high intensity arc consumes over twice the energy consumed by the medium intensity arc.

Color.—The determination of the most suitable color of searchlight beams was a problem of absorbing interest. This characteristic was found dependent principally on the temperature of the source. At relatively low temperatures; that is with low intensity arcs having a current density of about 0.1 ampere per square millimeters, the color is reddish yellow. Ingredients in the cores of the carbons can be used to modify the color slightly. At intermediate temperatures, such as produced by medium intensity arcs having a current density of about 0.4 ampere per square millimeters, the color of the beam is greenish yellow. Ingredients in the cores of the carbons have little modifying effect on the color. At high temperatures such as produced by high intensity arcs with a current density of about 1.0 amperes per square millimeters, the beam color is bluish white and is uninfluenced by ingredients in the cores of the carbons.

The colors of searchlight beams can be accurately controlled by the use of filters. These reduce the amount of light in the beam from 20 to 50 or more per cent. Their use has been abandoned for military purposes, where the amount of light is of paramount importance.

Absorption.—The absorption of searchlight beams under various atmospheric conditions has been studied. The investigations have not been completed. They are still in progress. Initial results indicate that the amount of light returned to an observer near the searchlight varies inversely as the sixth or seventh power of the range. It has also been found that the shorter wave lengths of light energy are absorbed more rapidly by the earth's atmosphere than the longer wave lengths. Experiments with a blue-white 150 ampere high intensity arc in a 60 in. parabolic glass mirror showed the beam to appear distinctly yellow at 20 miles. Radiometer tests show that 75 per cent. of the light energy in the yellow part of the spectrum is dissipated in 7.2 miles of clean dry air near the earth's surface.

Mirrors.—Mirror sizes and shapes were the subject of numerous investigations. The exigency of the situation precluded long experimentation. Samples of existing designs were secured. Comparative tests were made. Remarkably little difference was found in the beams projected by those designs whose reflecting surfaces were true geometric figures either parabolic or nearly so, and which were used with arc sources of light.

Focussing.—Focussing determinations were made photometrically to establish a basis for future practice. It was found that the beam could be broadened by moving the positive carbon closer to the reflector, but that this involved a loss of light. Moving the positive carbons 2 per cent. out of focus reduced the maximum illumination 70 per cent. and formed a dark spot in the center of the beam.

Front Glass.—The front glass or door or lense of a searchlight was first given attention by Dr. Abbott. While observing a searchlight beam he remarked the large diffusion caused by the front glass. Later investigation revealed that the glass used was relatively poor optically and that it diffracted some of the light of the beam. It was also found that dust and dirt on the front glass further reduced the light in the beam.

Tests were made to determine the ordinary light losses caused by the front glass. Three organizations co-operated. They made an exhaustive series of measurements at ranges from 1,000 ft. to 3,000 ft. It was found that the front glass cut off an average of 25 per cent. of the beam light.

Fig. 9.—Stationary skyline silhouette targets for comparison of searchlight beams at 3000 ft. range.

Fig. 10.—Stationary target scale and photometer house for beam illumination tests at 2300 ft. range.

Fig. 11.—Movable target screen and photometers for beam illumination tests at 930 ft. range

Fig. 12.—German observation airplane, top view. Typical air target.

Fig. 13.—German observation airplane, side view. Typical air target.

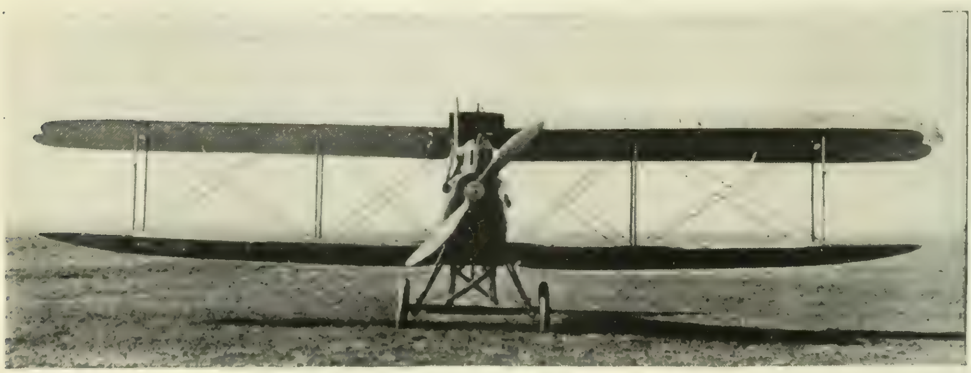

Fig. 14.—German observation airplane, front view. Typical air target.

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Fig. 15.—German 110 cm. searchlight on horse drawn vehicle. Searchlight uses 38.5 mm. positive and 14 mm. negative electrodes, and 150 amp. with 74 volts at the arc.

Fig. 16.—German automobile searchlight power unit.

Fig. 17.—Typical German portable searchlight power plant.

Fig. 18.—Early design of French automobile searchlight power unit with 90 cm. projector.

Fig. 19.—Latest design of French automobile searchlight power unit with 90 cm. projector.

Fig. 20.—American searchlights in operation on Western Front in 1918.

Fig. 21.—American design of automobile searchlight power unit with 150 cm. projector, on Western Front in 1918.

Fig. 22.—American 1917 design automobile searchlight power unit with 90 cm. projector.

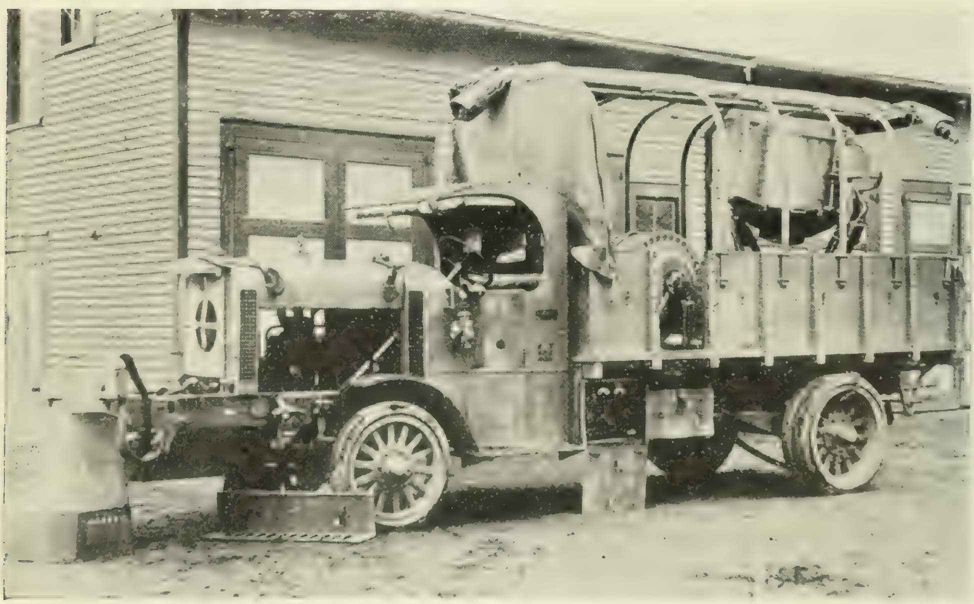

Fig. 23.—American 1917 design automobile searchlight power unit with 90 cm. projector. Covers and hoods have been removed to show projector, engine, generator, cable, switchboard and other details. Uses Mack type AC engine and truck.

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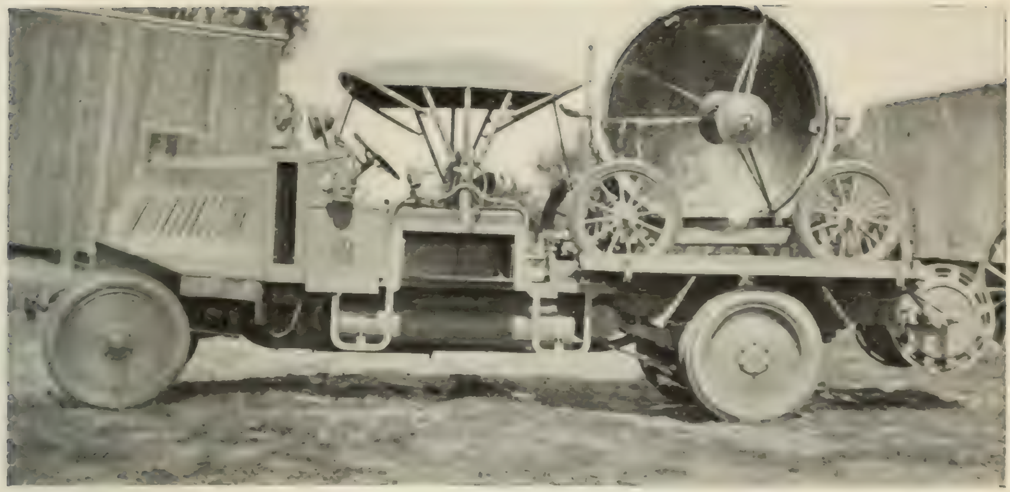

Fig. 24.—American 1918 design special automobile searchlight power unit with 60 in. projector. Uses Mack type AB chassis, Mack type AC engine and open type searchlight.

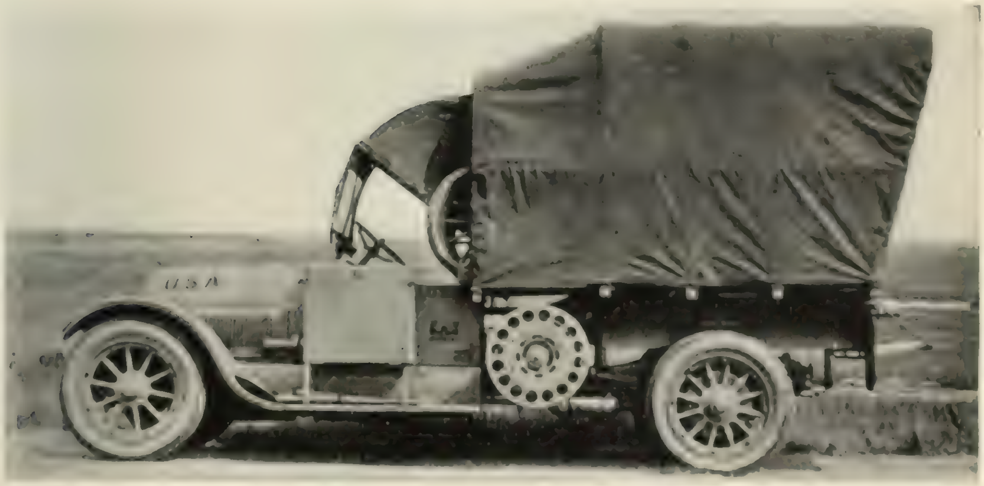

Fig. 25.—American 1918 standard design automobile searchlight power unit with 60 in. projector. Uses 145 in. Cadillac chassis, model 57 engine and open type searchlight.

Fig. 26.—American standard field searchlight and automobile power unit. Searchlight is run onto the power unit via ramps when it is to be transported.

Searchlights were next operated without front doors. Trials were made with 24 in. barrels containing 75 amperes high intensity arcs, and 36 in. and 60 in. barrels with 150 ampere high intensity arcs in all kinds of wind and weather. Their operation was found successful in all but rare combinations of wind and angular position of the searchlight barrel. In these cases it was found that the walls of the barrel caused eddies of air which disturbed the arc stream.

The successful operation of barrel searchlights without front doors was a leading factor in suggesting the development of open type searchlights.

Target Finding.—Target finding determinations proved a most interesting and valuable contribution to the art. Previous investigators had contented themselves with separate photometry or other measurement of searchlight arcs and beams. The lack of suitable standards, the intensity and unsteadiness of the source and the important effects of atmospheric absorption were neglected. The results were neither absolute nor comparative.

The limits of the older forms of testing were soon realized. It was seen that more reliable methods were necessary. The field was carefully surveyed and the problem studied. A return was made to first principles. One or more sources of light comparable with the source to be examined were arbitrarily made standards. These were chosen from sources which had been or were being used under service conditions and concerning whose performance some data was obtainable. The visibility of distant targets illuminated alternately by the standard sources and the unknown source was determined when viewed by a number of observers at service distances from the source and the targets.

Fixed area targets were the first form used. They were eighteen in number. They were rectangular in shape. Their sides were in the proportion of 5 : 1. They were painted dull black. The largest had an area of 500 sq. in. The smallest had an area of 2.5 sq. in. They were located on a sky line about 3,000 ft. from the searchlights under test. The number visible when illuminated by any beam gave an indication of the finding power of that beam. The inverse relation of the least mean areas observable when illuminated by the several searchlights gave a comparison of their relative finding powers.

Variable area skyline targets followed. They consisted essentially of a long canvas roll mounted on a cylinder in the same fashion as a window curtain. The surface turned toward the searchlight was painted dull black or in a series of combinations of dull white and dull black. They are used in the same manner as the fixed area targets. Their principal advantage is that the observations with them are less likely to be biased since the observers have no gauge of the least area visible.

Airplanes and ships are being used extensively as comparison targets. They are the preferred kind. Their use is relatively simple. They are caused to pass successively through the standard and unknown beams at six to ten ranges on three or five or more nights. The number of times they pass through each beam is noted by observers on them. The number of times they are seen to pass through the beams is noted by observers located at service positions. A ratio of the mean number of times the targets are observed to pass through the beams and the actual number of times they passed through gives an indication of the finding power of the beams. A comparison of the ratios of standard and unknown beams gives a direct comparison of their finding powers.

Comparison target finding tests are based on the assumption that lights of known finding power under service conditions are used as standards. These tests then form a simple, accurate and rapid method for the determination of the service utility of a new or modified searchlight. The tests were used with marked success in comparing mirror sizes, mirror colors, mirror shapes, front glass losses, medium and high intensity arcs, color screens and over twenty designs of searchlights.

Observer's Positions.—Observer's positions have always been known to influence the finding power of a searchlight. Many observations were made from time to time, but no co-ordinated results obtained. The problem was given special attention in the spring of 1918. A series of tests was made with airplane targets at Ellington Field, Texas. A 36 in. barrel searchlight with a 150 ampere high intensity arc, forty observers on a 6,000 ft. baseline and an airplane flying at elevations from 3,000 ft. to 6,000 ft. and ranges of 10,000 ft. to 20,000 ft. were used. Observations were taken on a number of nights. Over eight hundred

readings were obtained. The collated results indicate that the best observing position is in the axis of the trunnion of the searchlight and from 300 ft. to 1,000 ft. distant from it.

Designs.—The design of searchlights and searchlight equipment to meet the new warfare conditions required radical changes in the fundamental ideas previously held. The service needs were collected and analyzed. The views of collaborators and liaison officers were obtained. Future operations and tendencies were considered. Problems were formulated and assigned to selected groups of engineers. Their queries were invited and answered. Their products were examined during the progress of development. The final samples were given rigid and exhaustive tests.

Five designing engineers with their assistants co-operated with the War Department. Each formed a group of keen, skilled, enthusiasts whose knowledge, interest and efforts resulted in the successful development of a number of new, novel and epoch making designs.

Barrel Searchlights.—The barrel searchlights available at the beginning of hostilities were intended for fixed installations. A portable type was needed. The problem was submitted to the Sperry Gyroscope Company and the General Electric Company. They assigned Messrs. Preston R. Bassett, John L. Hall and E. J. Murphy to consider the requirements. The first result of their study was a standard 36 in. barrel searchlight with a four-wheeled carriage instead of the remote control base. This reduced the weight from 4,000 pounds to 1,600 pounds. Next they modified the design and produced a 60 in. light barrel weighing 1,800 pounds complete with carriage. The mechanisms of these searchlights are noteworthy. They are automatic yet very simple. The number of parts in them is less than one-fifth the number in the previous standard designs. They weigh only one-fourth as much as the standard designs, yet are more rugged and function better.

Open Searchlights.—The open type searchlight was conceived by Major Richard Wheatley Lewis, Engineers, in May, 1918. He was deeply impressed with the need for a lighter weight searchlight than any available. He saw the desirability of having one which would combine lightness with ruggedness, simplicity and

ease of operation. He studied the results of experiments made in the United States and sketched a design which eliminated all but the basic essentials of a searchlight.

The problems of design were submitted to a group of army engineers, the General Electric Company and the Sperry Gyroscope Company. Captain L. C. Josephs, Jr. and Messrs. C. A. B. Halvorson and P. R. Bassett were assigned to crystallize Major Lewis's conception. They developed and within two months placed in production a 60 in. searchlight of remarkable properties. It weighed only one-fifth as much as the previous standard. It had one-twentieth of the bulk and cost only half as much. It was infinitely simpler and could be produced in less than one-fourth the time required to produce the old standard. It used the same mirrors and carbons as the old designs. It was uniquely adapted for the service conditions encountered.

Improved open type searchlights followed the successful initial designs. The carriage was made stronger and lighter. The mechanism was made simpler. A tripod mounting was made for a 30 in. size. A litter carrier was made for the 60 in. size. The finder was simplified and improved. The controls bettered. The result is a searchlight design which will accommodate the wide variety of arc light sources and mirrors to meet the many service conditions encountered.

Power Units.—Mobile power units were as essential as mobile searchlights. They were required to be dependable and quiet in their operation. Their design was submitted to Lorimer D. Miller, Major, Engineers; L. C. Josephs, Jr., Captain, Engineers, and Mr. Harry S. Baldwin of the General Electric Company. Two schemes were developed. Both used an automotive engine as prime mover. One is the so-called Mack design. It had the generator located in front of the engine and supported beyond the automobile chassis. The other is the so-called G. E. Cadillac design. It had the generator located on a quill between the automobile transmission and the differential and supported inside the automobile chassis.

The Mack design was an adaptation of French practice developed during the war period. It eliminated the belts, chains and other links of the French systems and placed the generator on an

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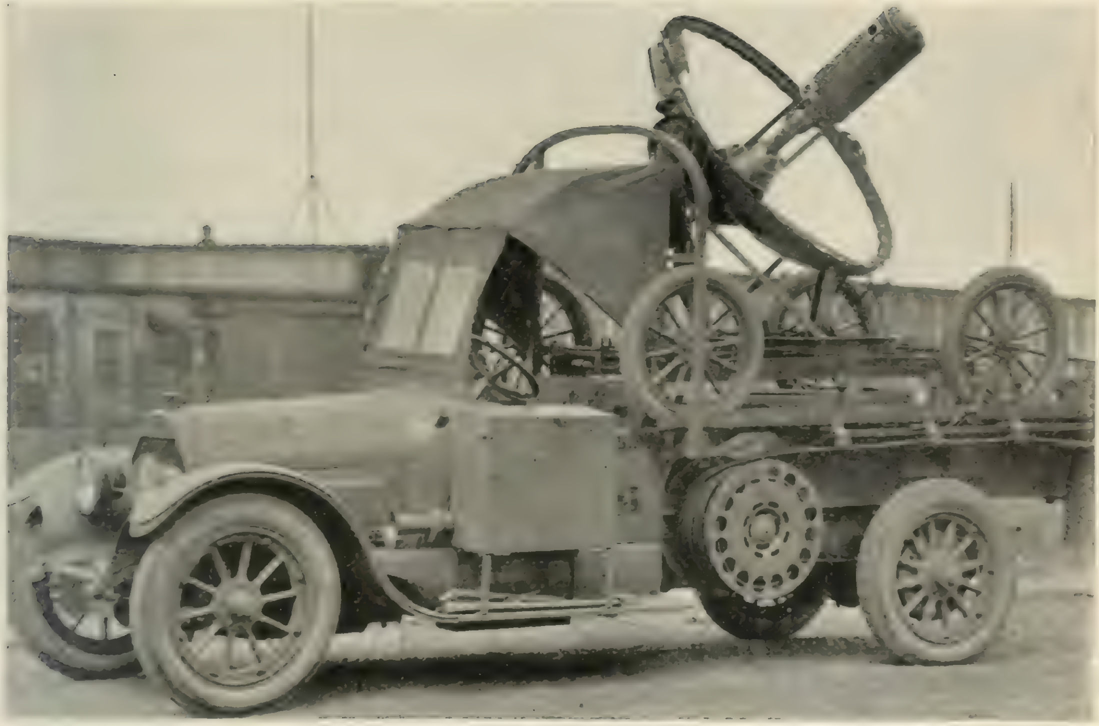

Fig. [illegible]—American standard field searchlight on power unit. Cover has been removed to show arrangement of parts. Searchlight is operable as shown.

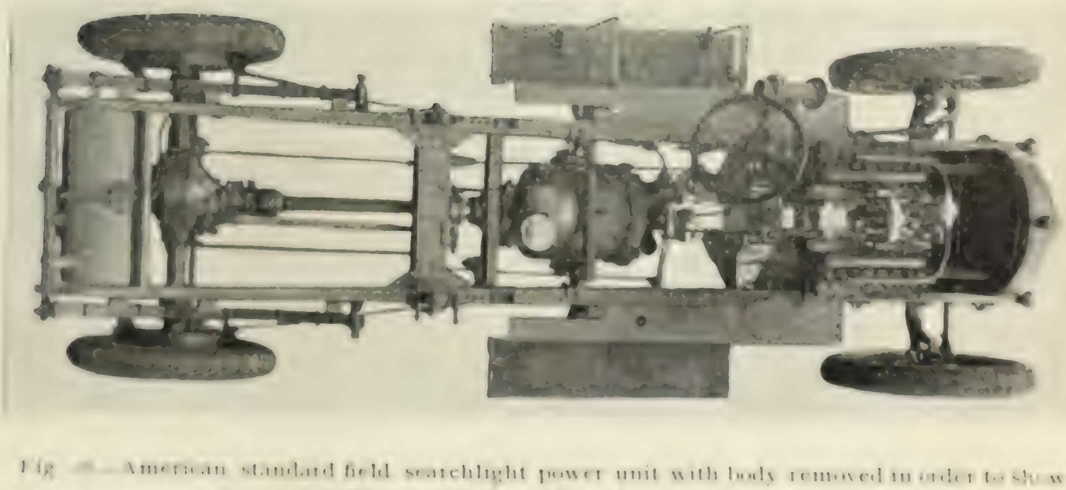

Fig. [illegible]—American standard field searchlight power unit with body removed in order to show arrangement of engine and generator.

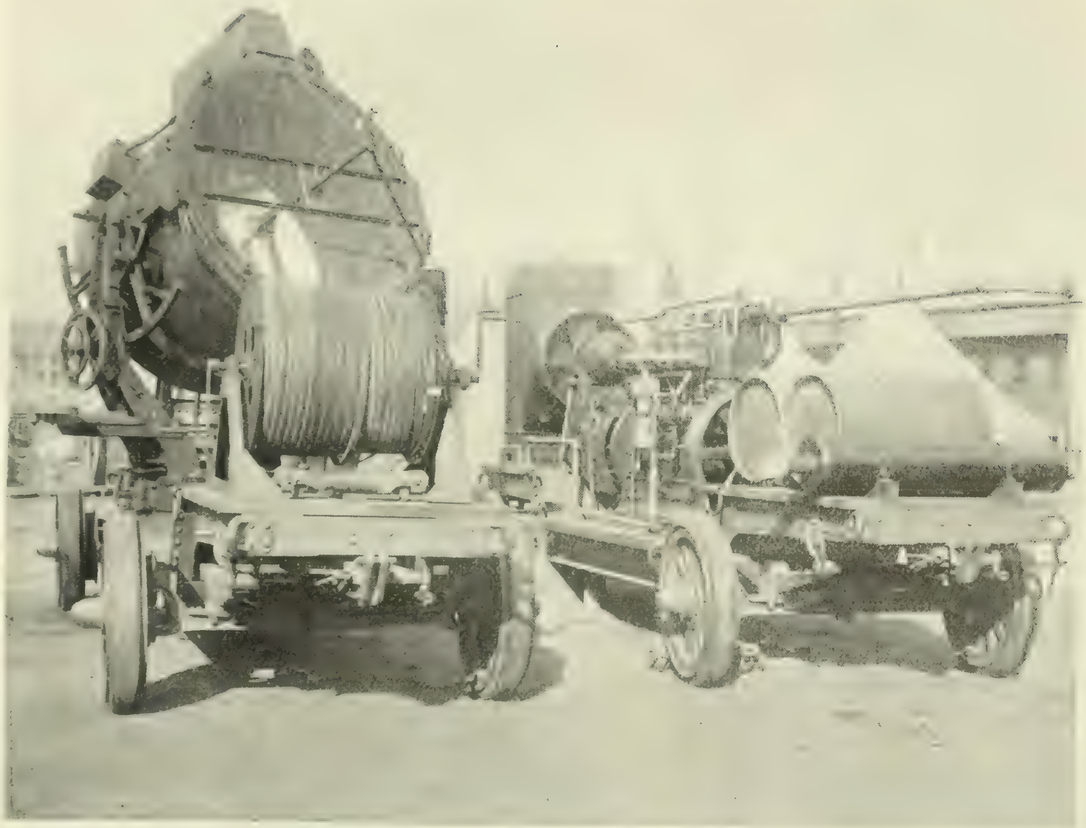

Fig. 29.—Early American design of 60 in. portable searchlight and power unit.

Fig. 30.—American 1917 design of 36 in. wheeled barrel searchlight used with automobile power unit.

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Fig. [illegible]—American [illegible] of [illegible]-in. open type searchlight used with automobile power unit.

Fig. 12.—American 1915 design of [illegible]-in. open type searchlight used with automobile power unit. Wheels have been removed to show intrenching possibilities.

Fig. 33.—American 1918 design of 30 in. open type searchlight, model G.

Fig. 34.—American 1918 design of 30 in. open type searchlight, model S.

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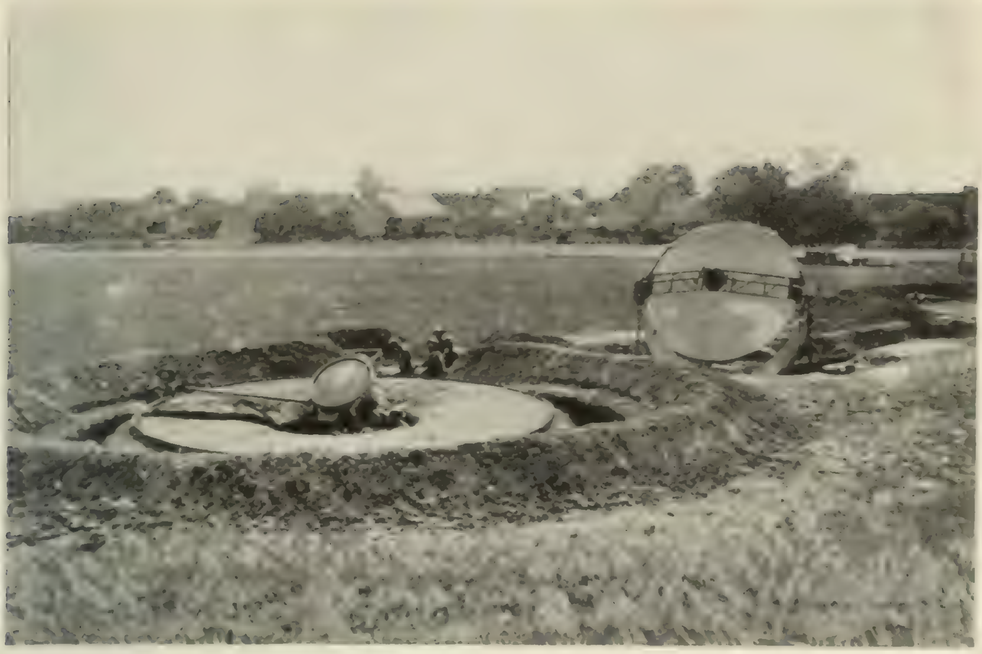

[illegible] —American searchlight position on Western Front in 1918. It is equipped with 60 cm. searchlight and 3 m. sound locating parabaloid.

Fig. [illegible] —American searchlight position on Western Front in 1918. It is equipped with [illegible] in. high intensity barrel type searchlight and 3 m. sound locating parabaloid.

Fig. 37.—The capitol Washington, D. C. A photograph taken at night, illumination being furnished by 1918 design 60-in open type searchlights operated from mobile power units such as shown in Fig. 25.

extension of the engine crank shaft. This design permitted standard truck units to be modified and used as mobile searchlight power units. It also permitted a limited operation of the searchlight and truck motive power simultaneously. The design was projected in December, 1917. One hundred and eighty units using 5½ ton Mack trucks were built. They were equipped with extra radiator and extra water supply and carried a 115 volt 15-kilowatt generator, a 36 in. wheeled barrel searchlight, 500 ft. of cable, rheostats, etc. About 30 units reached the American Expeditionary Forces in France where they were successful on hard roads.

The G. E. Cadillac design was a distinct departure in power unit construction. Similar to the Mack, it uses a standard automobile engine and chassis. In addition, however, it uses the standard water reservoir and cooling equipment. The generator is placed concentric with the propeller shaft and connected to it through a quill. A standard Cadillac clutch and gear shift lever enable the engine to be connected to either the generator or the automobile propellor shaft.

The Cadillac idea was suggested in June, 1918. A sample was ordered in July, 1918. Delivery was made in September. A short but thorough test was made in the United States. The sample was then shipped to France where it was received and placed with the Second American Army early in October. It carried a 105 volt 20 kilowatt generator, 600 ft. of cable, and a 60 in. open type searchlight. Ninety additional units were authorized soon after the sample was started.

Extensions of the Cadillac idea have been made. A 50 kilowatt unit has been completed. A 7 kilowatt unit is being constructed. The three models form a unique line of portable power units employing automobile designs which have been standardized for the general service in the Army.

Future.—The future of military searchlights is assured. The remarkable advances in aeronautics alone provides a wide field for their employment as detectors, beacons, landing lights and signals. Their development has but just started. They will undoubtedly be wonderfully improved in the next decade.

DISCUSSION.

C. Gabbot: I had the pleasure of being associated with Capt. Lichtenberg early in the period of the developments of searchlights which he has so ably summarized in his paper. I am glad to have this opportunity of saying how greatly I have admired his devotion to the problem of improving the searchlights for military purposes, and how remarkable the improvements seem to me which have been made, as the result of the intensive campaign with which he has been associated in the Engineer Corps of the Army.

Especially notable, it seems to me, is the great reduction in weight and cost with corresponding increased mobility of the searchlight apparatus, and hardly less so is the extraordinary increase of penetrating power due to the introduction of the great 60-inch lights in field practice.

The two directions in which I look to see still further progress relate, first, to the distribution of light in the spectrum of the arc, and, second, to the control of the direction of the beam from distant stations. With regard to the first, and referring to Fig. 3 of Capt. Lichtenberg's paper, it will be seen that the amount of energy included between the wave lengths 0.5 and 0.6 microns, that is to say the amount of energy which is most efficient for purposes of vision, is only 14 per cent. of the whole in the spectrum of the high intensity arc, and only 10 per cent. of the whole in the spectrum of the medium intensity arc. What is highly desirable and perhaps is not beyond the inventive capacity of research men, is to produce an arc which, like the mercury vapor lamp, confines its radiation sensibly within the range covered by the sensitiveness of the human eye. If this could be done, so that the energy of the current could be expended for useful purposes almost wholly instead of almost wholly for producing heat without valuable results, it is clear that either one of two two things might happen. Either the power plant might be reduced in weight several fold, or else the penetrating and illuminating power of the beam might be increased several fold with the same power capacity. It is well known that the spectrum of certain of the elements, as, for example, thallium, is almost solely confined to lines which lie in the region of utmost visibility. Unfortunately thallium is a low melting point metal and it is not

obvious how it could be made use of in the production of an intense arc. I have confidence, however, that improvements along this line may be made in the future.

In the second place, experiments which were made by myself and colleagues very early in the investigation of searchlights convinced us that the greatest advantage was to be obtained if the eye of the observer could be relieved of the stray light which results from being stationed near the beam. If the observer could be located a thousand feet away from the beam or more, and have perfect control over it by means of quick acting automatic devices, so that with the slightest touch he might move it about just as readily as if he were on the spot, the finding capacity for moving targets would be increased very much. Several devices are now under development to accomplish this purpose; and doubtless, if not already, then within a few months, the distant control of the searchlight will have passed the experimental stage and will become a producible reality. This, it seems to me, will be of a very great value in the arc, for a 24-inch searchlight used under the favorable conditions which may then be realized would be in my judgment for finding purposes better than the 60-inch searchlight if used with the observer near the lamp.

S. G. Hibben: There is scarcely any other example of the rapid progress of development resulting from intensively applied science that can equal this case of the Arc Searchlights. What was actually done under stress of war conditions cannot be fully realized by this brief survey of the progress made. The greatest regret is that these developments could not have been made sooner, and it is our earnest hope that they will not again become dormant.

I had much to do with the design of searchlight apparatus in this country, and later went overseas with a searchlight battalion. The experiences at the front brought out what features should and must be a part of such apparatus, and we learned that our searchlights—the anti-air-craft types, of 1917, even thought to be the very best we could produce at that time, were absolutely unserviceable in France.

Among other things, the mobile field units must be positively unbreakable. Hence the seeking for metal mirrors and the use

of bakelite-micarta gears, transite or fibre switch-boards, cushion and not pneumatic tires, fool-proof electrical connections and sturdy, automatic control devices.

We found the rain and moisture and mud to be our constant foes. The mirrors if clouded or dirty become useless, because "ghosts" or phantom objects in the beam destroy one's ability to discern such a poor and fleeting target as an enemy plane. Then, too, a field unit absolutely must be light in weight. Transportation conditions are terrible in any war, and most of our searchlights failed, or never reached the scene of action, on this account. They must possess their own power, and though having great traction and reasonable speed, must not be too large to prevent "digging in" speedily.

For future operations against aircraft, it seems probable that no projectors smaller than 60-inch (mirror diameter) or 150 Cm., will be satisfactory. Development must still be made to eliminate "spill" light, and affect better concealment of the source. This also brings up the questions of color of light, and adds to the research problems the one of invisible light, solved to some extent during the latter part of 1918, but not completely so.

Since a chief function of the anti-craft light is to keep in the illuminated field and to blind the enemy, the beam must be uniform and intense, with least divergence, which means a small positive arc crater, and a current density of about one ampere per sq. Mm. Beam traversing is difficult and necessitates slow and uniform motion at the lamp, for at a range of five thousand yards a degree's motion per second means a speed of beam travel of over 87 yards per second, nearly 3 miles per minute.

The use of radium luminous scales on meters, as well as azimuth and elevation circles, is another interesting and undeveloped feature. Elimination of noise is another problem for further research, and the signaling devices can be further improved.

Even after the cessation of warfare, our searchlight development will bear fruit in the adaption of guide and signal lights for aerial navigation, and to a lesses degree for maratime service. Much yet remains undone, but so much has recently been done that the story of the searchlight progress reads like a romance that will certainly interest everyone.

Part II

A UNIVERSAL PHOTOMETRIC INTEGRATOR.*

BY FRANK A. BENFORD.

Illuminating Engineering Laboratory, General Electrical Company, Schenectady, N. Y.

Nature of Tests.

A large number of tests of beam flux from large military searchlights have been completed. These tests determine total beam flux and nothing else. On smaller units, such as a 500 watt floodlighting unit, the beam has been measured zone by zone, and the beam intensities thus arrived at. Another use for the integrators that is contemplated is the analysis of crater brilliancy of large arcs. In this work an image of the crater is thrown against a sheet of metal having an opening that allows the particular section of the image under investigation to pass on into the integrator. Both lamp efficiencies and reflector efficiencies have been determined and later, when the searchlight tests are finished this type of test will become relatively more important, especially in the case of big units that have a large capacity for absorbing light reflected back from the integrator.

* ADDITIONAL TEXT to be inserted in Vol. XV, No. 1, February 10th, 1920, issue at page indicated.

MECHANICAL DETAILS.

Framework.—The skeleton of the hemisphere is 2 in. by 2 in. by 3/16 in. T-iron, with a 3/8 in. plate 18 in. in diameter at the pole or junction point of the ribs. The rim is a 4 in. by 3 in. by 3/8 in. angle iron made in two sections and joined on heavy bearing blocks at top and bottom where the lamp standards are held. The hemisphere is supported at eight points so that the weight is distributed along the 4 in. by 4 in. by 3/8 in. T-irons that carry the hemisphere and platform. Four hardened steel wheels provided with ball bearings carry the entire structure, which completed weighs about 3,000 pounds, and these wheels are so placed that the flexibility of the lower T-iron allows the four wheels to ride easily over minor imperfections in the track without straining the plastered shell of the integrator.

The frame of the iris shutter is attached to the rim of the hemisphere by rods and wood spacers. The shutter rides on its own wheels and can move slightly in a vertical direction independently of the rest of the instrument, and this contributes to easy riding.

Backing.—The outer surface of the shell is "Marbleloid," a composition that is used for floors and has the advantage of being light, durable and almost totally free from expansion due to moisture or temperature changes. This material is laid on a double web of expanded metal. The heavy 3/4 in. expanded metal is used for strength, and the light 1/4 in. expanded metal was put on merely to hold the material while in a plastic state. The saving in weight through the use of "Marbleloid" in place of concrete is about 500 pounds per instrument.

Preliminary experiments showed that "Marbleloid" and the Keene's cement used for the inside finish would not bind. Portland cement will bind with both, so a thin coating of Portland was applied before putting on the inner surface with entirely satisfactory results.

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BY FRANK A. BENFORD.

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Purpose of Integrator.—The photometric instruments described below which are the essential parts of the "Indoor Searchlight Range" have been previously brought to the attention of this Society; the former paper was in the nature of a mathematical investigation of the possibilities of the instrument, plus a limited amount of test data taken with a small model. The outcome of these preliminary data made it seem probable that the instrument would be useful in the testing of military searchlights and, accordingly, the construction of the integrators and other equipment was begun during the war to aid in the development of anti-aircraft projectors. Strictly speaking, the integrating photometers, when used for any searchlight test, consist of a photometer track 150 ft. long, on which rides a hemispherical light-collecting shell with a small portable type photometer attached and a system of curtains along the track to absorb stray light. Aside from this original purpose, the hemisphere and its photometer may be used for the measurement of the light from arc or incandescent lamps, with or without reflectors, and in this work the unit under test is enclosed in the hemispherical shell by means of an iris shutter provided for that and other purposes, and the long track and curtains are no longer parts of the integrator.

Facing.—The inner, or optical, surface of the integrators is a coating of Keene's cement swept to a true spherical form. This cement has a high coefficient of reflection, is non-selective, does not discolor under heat and is hard enough to resist the penetration of dust or smoke. The surface can be dusted with a feather duster, and any remaining dirt can be sandpapered off. It is believed that this surface can be kept in better condition than a painted surface, as experience with soft white diffusing paints shows that they quickly collect dirt and turn yellow if exposed to intense radiation. This latter point is of considerable importance because the energy of the beam entering the inte-

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grator has often been of the order of 15,000 watts, and the flux of light approaches 200,000 lumens with high wattage projectors.

Before any photometric tests were made, the entire surface was sandpapered with double naught paper, the strokes being always around the pole, or photometer position. This direction of furrow in the surface gives the maximum diffusion for light entering parallel to the axis. In all future cleaning operations the same grain of paper will be used and the strokes made in the same direction, thus insuring the permanency of the present diffusion characteristics of the surface.

Shutter.—Each integrator in provided with an iris shutter which may be used to diaphragm down the opening to fit the entering searchlight beam, or totally enclose a standard lamp or test unit placed in the plane of the opening of the hemisphere. The shutter can open to the full diameter of 110 in. and it can be closed down to 5 in. diameter without danger of injuring the leaves which are of 0.034 in. sheet iron. The leaves have not sufficient stiffness to stay flat at all openings, and they are supported between the optical wedges and a web of fine piano wire. It is only when the shutter opening is between 3 and 4 ft. diameter that the leaves need support, and the ends of the optical wedges are slanted outward to furnish this support from the inside. The outside ring carries the piano wires, which are stretched tight and have their crossing points near the tips of the wedges. The shutter is operated by means of a hand wheel, sprocket wheel and chain. The two lower bearings are provided with ball bearings as they carry most of the weight. The four other bearings are plain.

Compensating Mirror.—The mirror that is held in front of the photometer opening, and that fulfills the double function of shield and reflector, is spherical in form and silvered on the concave, or back, surface. The radius of curvature of this surface is 4.35 in. and the thickness of the glass is 0.10 in. The total arc from edge to edge is 92°. A star figure made of dull black paper and having twenty-four rays is shellacked to the mirror. The proportions of this star, which were determined by a cut and try method, are such that, with the exceptions noted later, all parts of the surface of the hemisphere give equal photometric readings

Part II

Compensating Mirror.

	Inches
Radius to base of rays	2.00
Width of base of ray	0.40
Sides of rays straight to radius	3.16
Width of ray at radius 3.16 in.	0.22
Rays taper to point at radius	3.25
Open space between bases of rays	0.10

In order that the 4-in. solid center of this star might conform to the curvature of the glass, twenty-four knife cuts are made from the bases of the rays almost to the center. The edges of the cut are then overlapped and the paper shellacked firmly to the glass.

Photometers.

Photometers.—Two photometers of the Weber type, especially adapted to this work, were made by the Bausch & Lamb Optical Company. The range of readings with a fixed photometer lamp current is 100,000 to 1, and a blue screen may be inserted in one side of the field to get a better color balance when testing arcs. More than ordinary care must be taken in setting the photometer in position, as this type of integrator does not depend on multiple reflections to smooth out inequalities in the reading values of different points. For this reason the photometers are solidly attached to the steel shell, and the head is adjusted so that the milk glass is held in the plane of the opening.

* **ADDITIONAL TEXT to be inserted in Vol. XV, No. 1, February 10th, 1920, issue at page indicated.**

Design and Calibration Data.

If time had permitted, the phenomenon described would have been investigated further, as it seems possible that a glass blank without silver might reflect sufficient light to make the necessary compensation, and this without the troublesome multiple reflections near the mirror.

*** ADDITIONAL TEXT to be inserted in Vol. XV, No. 1, February 10th, 1920, issue at page indicated.**

for equal quantities of light. The layout of the star on flat paper has the following dimensions:

Wedges.—The optical adjustment necessary to correct for specular reflection of light entering the integrator parallel to the axis is made by eighteen metal wedges that have their bases attached to the stationary ring of the iris shutter. These wedges are 1/16 in. iron bent into T-sections and spot welded to an 1/8 in. base plate bent to the proper radius. The two entire sets of eighteen each were made before the calibration of the surface was completed, and the spare material was removed from half of each set, making the wedges alternately long and short, as shown in the photographs. Soft iron was used, as it was necessary to get the proper curvature by hand filing, working to a templet.

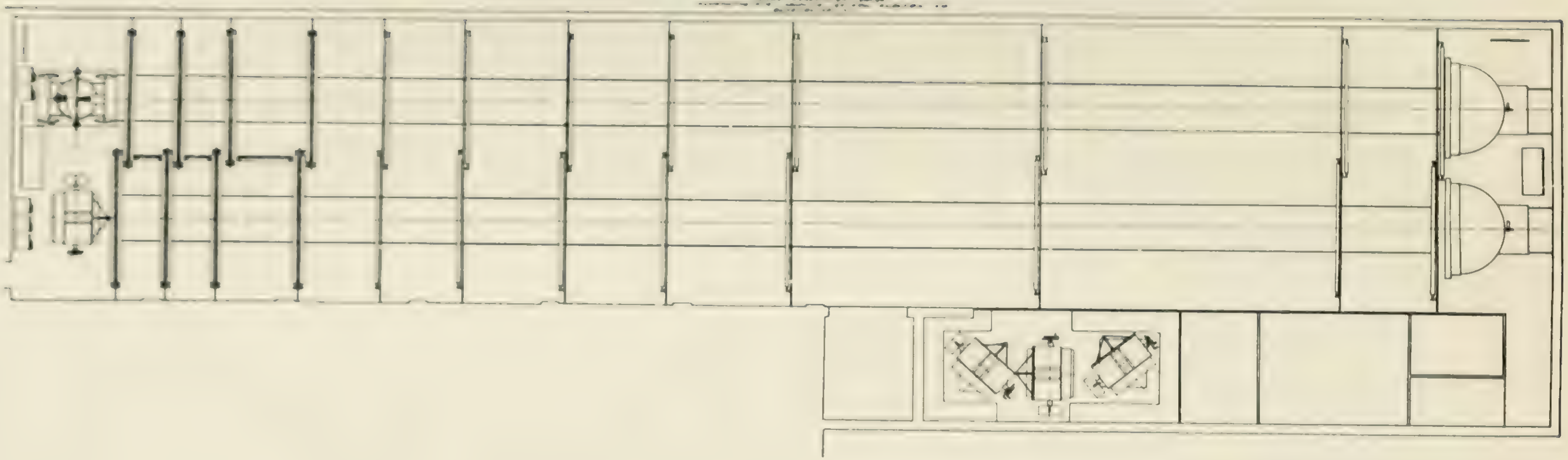
Design and Calibration Data.—An unexpected phenomenon was encountered in making the first spot calibration with the projection lamp placed at the center of the plane of the opening. The spot of light was 4 in. in diameter with a pronounced halo about 8 in. across. The area directly illuminated at one time thus was about 5° across, or a little less than the diameter of the mirror. When the light was on the back of the mirror holder, the readings (as compared with the weighed average of 100 for the entire surface) were about 70. At 6° from the axis; that is, just at the side of the mirror, the readings jump to 145 and then rapidly decrease to 100 at 10°. This high zone was found to be due to an integrating action between the mirror and hemisphere; outside of and additional to the regular reflection of the mirror. The greater part of this integrated light came from the part of the mirror that compensates the 70°, 80° and 90° zones. The integrating action thus could hardly be quenched without disturbing the balance of zones that are far more important on account of their greater area. After numerous forms of mirror figures had been tried without much success, it was decided to balance the high zone from 3° to 10° by two adjacent low zones; one from 0° to 3°, and a second larger zone from 10° to 20°. This was accomplished by reducing the regular reflection from the 10°—20° zone until the weighed average from 0° to 20° was equal to the average for the rest of the surface.

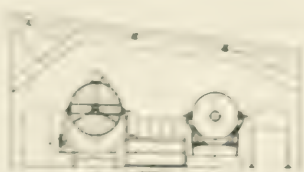
The total area included in these three zones is only 6 per cent. of the total hemispherical area, and it is not believed that the unbalanced areas will have any appreciable effect on test results, except possibly when testing a small projector beam that does not cover the entire opening. As a matter of precaution, the integrators will not be used with a shutter opening of less than 10 per cent. of the total area.

The determination of the star figure on the mirror was rather laborious, chiefly on account of the necessity of testing from edge to edge of the hemisphere after every change of any size. In the 40-in. model the integrating action was apparently weaker, and a change in the star figure to correct the 20° zone had little effect on the other zones, so that each point on the mirror could be altered with predictable results. Also, the illuminated spot covered about 10° and the high zone, which doubtless exists, was lost in averaging over the relatively larger area covered.

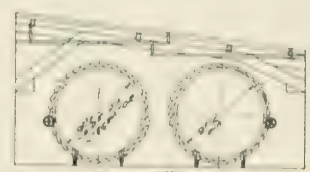
After the first integrator had been finished, a duplicate mirror was made for the second instrument. The surface was then investigated and the agreement with the first integrator was found to be fair, with the exception of the region from 5° to 25°, which gave readings several per cent. too high. Rather than change the star figure, another expedient was resorted to. Light that comes from the 70°, 80° and 90° zones strikes the mirror at near the grazing angle. Under this condition, reflection takes place almost independent of the presence or absence of the silver backing. It is this same region of the mirror that has the most active integrating action, so that the latter may be decreased by removing silver from near the rim of the mirror without greatly disturbing the direct reflection of light. A ¼-in. ring of silver was removed from the rim of the mirror, bringing the zone between 5° and 25° on the hemisphere down to normal, and the other zones were not appreciably affected.

The design of the wedges was comparatively simple. After the mirror was finished, the spot light was mounted on rails so that it could be moved across the front of the integrator, keeping the beam always parallel with the axis. There was no difference in the readings until the spot reached a point 25° from the axis, and from this point on the readings increased to 20 per cent. above the previous average at 70° which, on account of the fore-





SECTION SHOWING ARRANGEMENT OF CURTAINS



SECTION LOOKING IN FACE OF INTEGRATORS

22a

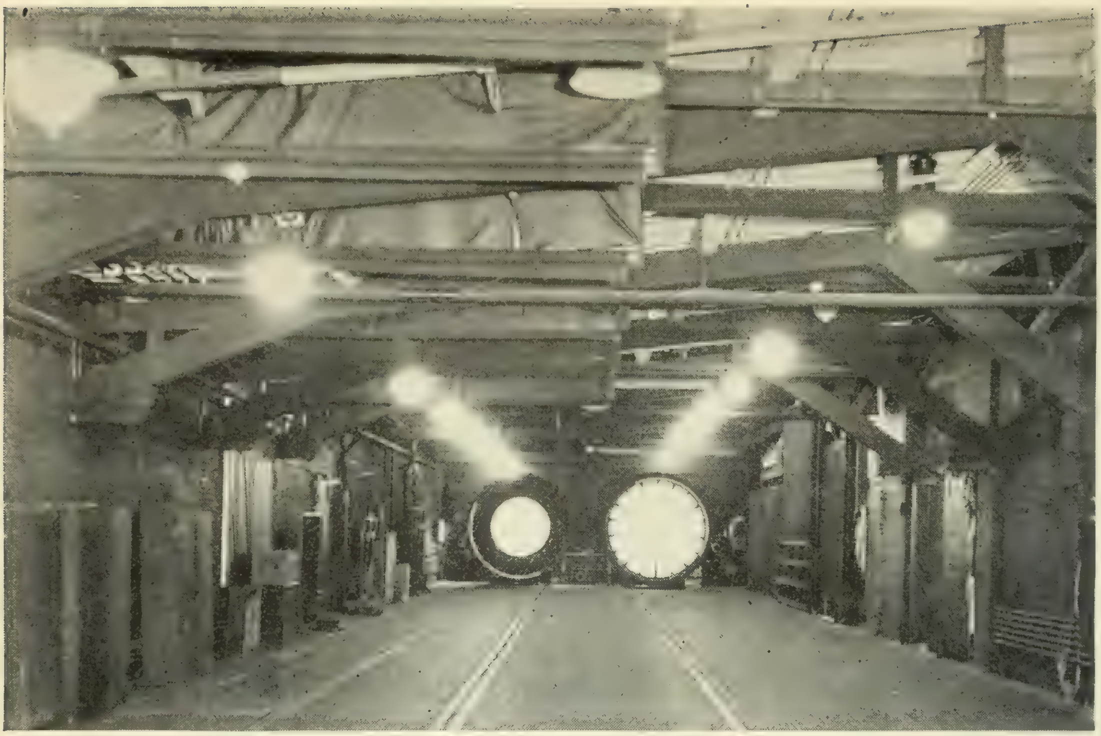


Fig. 1.—A General View of the Indoor Searchlight Range.
The curtains may be raised to give a clear floor for moving searchlights or for arranging tests that require a wide space.

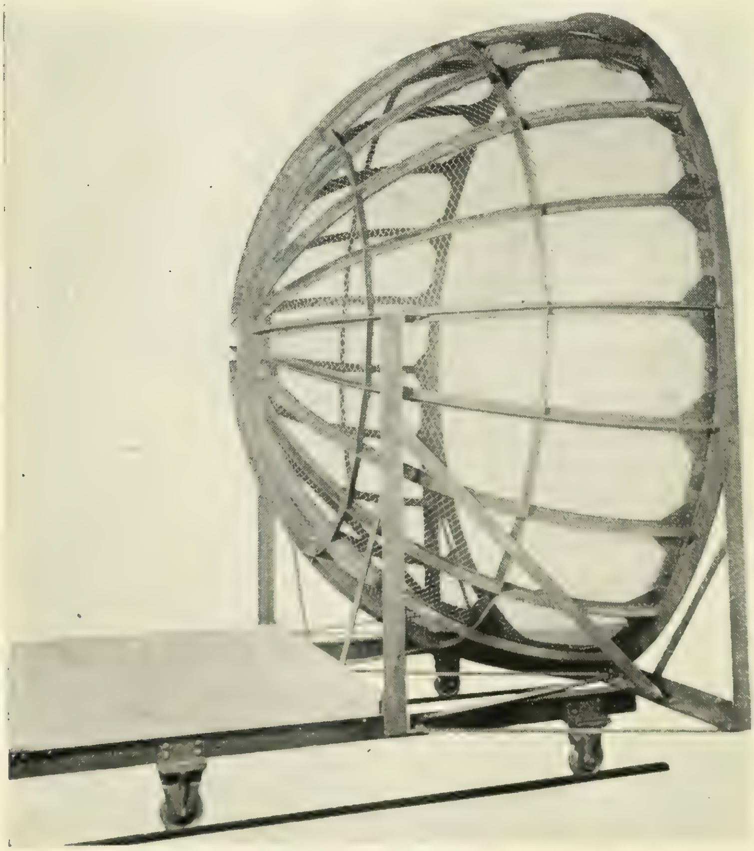


Fig. 2.—Framework and Platform of 110" Integrator.
A side view of the steel skeleton before the fine expanded metal and plaster were put on.

shortening of the surface, was the highest angle that could be reached. The test data, when plotted, indicated that at the rim of the hemisphere the readings would be 33 per cent. high. The wedges are so proportioned that they reduce the light in the various zones to uniform reading values.

When photometering a wide angle unit, the integrator is moved up to the unit and the angles of incidence on the various zones approach the normal; that is, the angle at which no wedge correction is needed. If the wedges are moved some distance away from the opening of the hemisphere, the wide bases of the wedges are removed from the cone of light entering the instrument, and their effect is less. By calculations it has been determined that with the wedges 12½ in. from the hemisphere, the correction is satisfactory for both positions marked 30° and 60° on the accompanying cut.

One of the features of the integrator that has worked out in a particularly satisfactory way is the photometric effect of opening and closing the shutter. The calibration with a standard lamp is done with the shutter closed, while in searchlight testing the shutter is used in various positions. A test was made with a wide angle incandescent projector placed in the plane of the shutter. In the closed position the shutter fitted tight around the rim of the projector and the instrument was light-tight. The difference between the readings in this position and when wide open amounted to only 0.4 per cent. which is within the usual limits of accuracy of searchlight photometry. This figure checks with the change of reading on the standard lamp with shutter open and closed. It should be mentioned that the wall and fixtures of the room are painted a dull black. The shutter is also dull black, and the net reflecting powers of shutter and room are almost equal.

An exploration has been made along the vertical line containing the standard and test lamps. Between the radii 13 in. and 38 in. (the limits of the test), the variation is certainly less than half of 1 per cent. and, as a result, in photometering lamps and reflectors, they may be placed anywhere along this axis up to 0.8 radius without effect on the photometric results. The results of this exploration were not forecasted by the previous tests on the one meter model which had a better diffusing surface. The working range there was limited to a half radius.

When testing large searchlights at a distance of 150 ft., one of the questions that came up is the amount of stray or fringe light that still remains in the beam. The successful operation of the photometers is involved in this question, and a large number of readings have been taken to determine the rate at which the light in the beam falls off with increased distance. On the accompanying curve the results are given on a logarithmic scale of distance. There was found to be a rapid decrease up to 105 ft., and from this point to 150 ft. the decrease was about 1 per cent. The decrease beyond 150 ft. is in all probability very small, perhaps not over 2 or 3 per cent. and the results at 150 ft. have accordingly been used without correction.

Types of Tests.—The beam from a large searchlight does not get into final form in the 150 ft. length of the indoor range, and the total beam flux is the only thing that can be measured. The projector is raised until its center is approximately the same height as the center of the integrator. It is usual to place the arc over the zero mark on the track, although there is no particular geometric reason for so doing. The feature of the test that requires the closest attention is the direction of the beam into the shutter opening. The beam from a hand operated arc is normally undergoing a constant change in size and direction, and unless the lamp operator is on the alert, the form of the beam will change due to the crater burning crooked. It has been the duty of two men to watch the adjustment of the iris shutter to the edges of the beam. At the searchlight the man in charge watches the operation of the arc and the direction of the beam. He is in constant telephone communication with the data man at the shutter, and the latter makes frequent small adjustments of the shutter opening.

The distance between searchlight and integrator is not important except for the elimination of fringe light around the edges of the beam, and for this reason the greatest possible range is always used. In occasional tests with large arcs taking from 300 to 500 amperes, the beam diameter at 150 ft. exceeds the shutter diameter, and the integrator is moved up to 125 or even 100 ft.

A test for beam intensities of a small projector whose beam formation makes it permissible to speak of beam candles at 150 ft. and less requires closer attention to the position of the hemi-

Fig. 3.—Front view of 110" Integrator.
The wooden bridge on which the operator is standing to adjust the test lamp is hinged on the right-hand end and when not in use it forms part of the shell between the hemisphere and iris shutter. A notch in the side wall of the bridge allows it to span the standard lamp in the lower socket and protects it from injury.

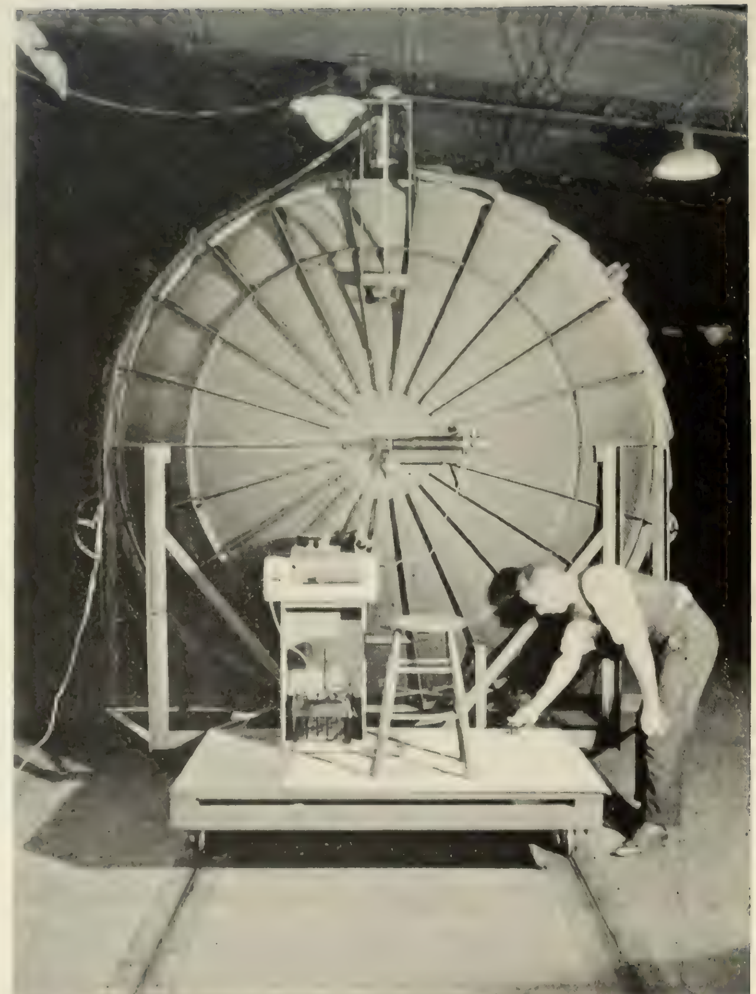


Fig. 4—Rear view of 110" Integrator.
Showing the photometer attached to the center of the hemisphere, and the two devices for turning the standard lamp and the test unit.

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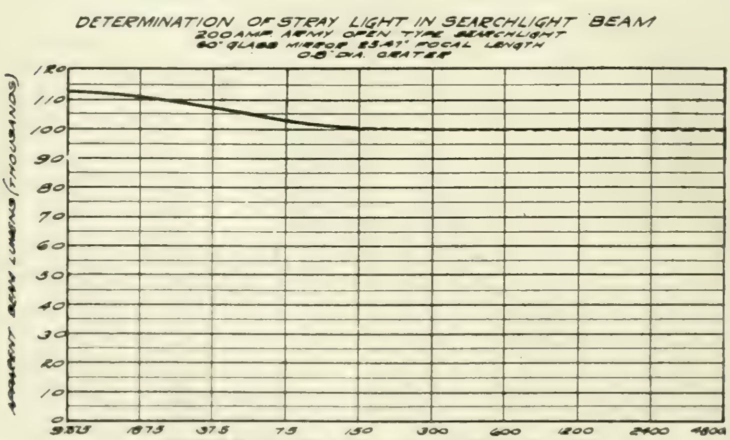
Fig. 5—The Curtains and Integrator as seen from the Searchlight.
Each range has twelve curtains with 114″ openings and four with 84″ openings for use when the integrator is brought up close to the test unit.



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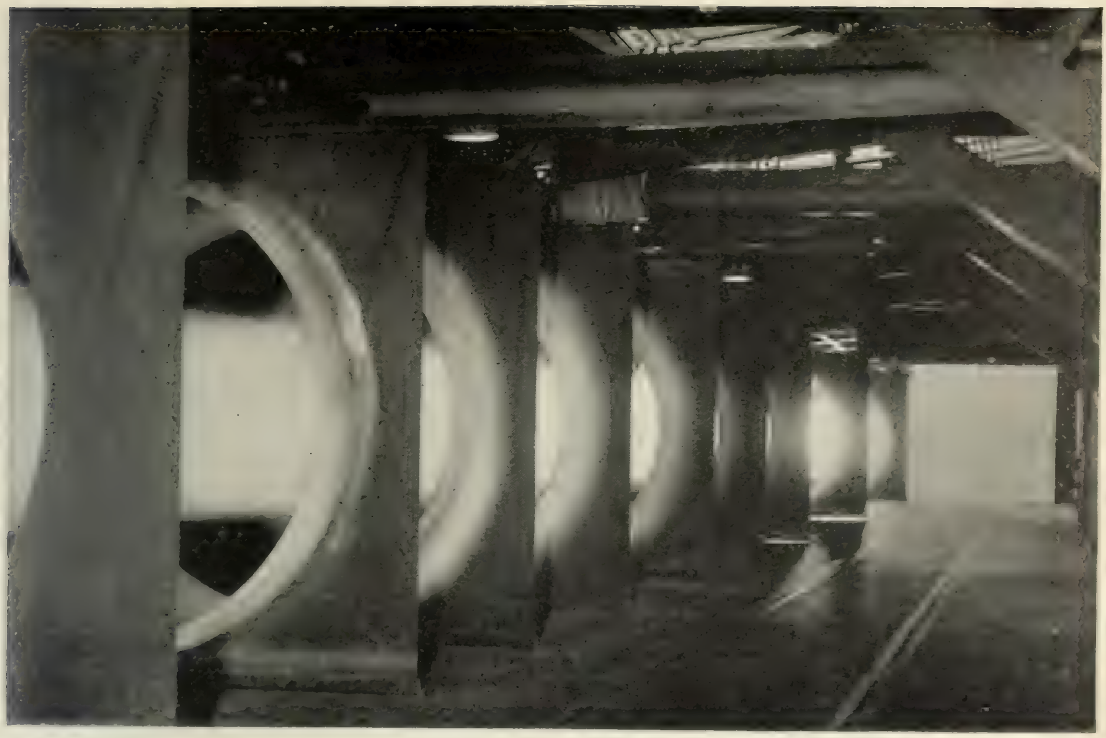
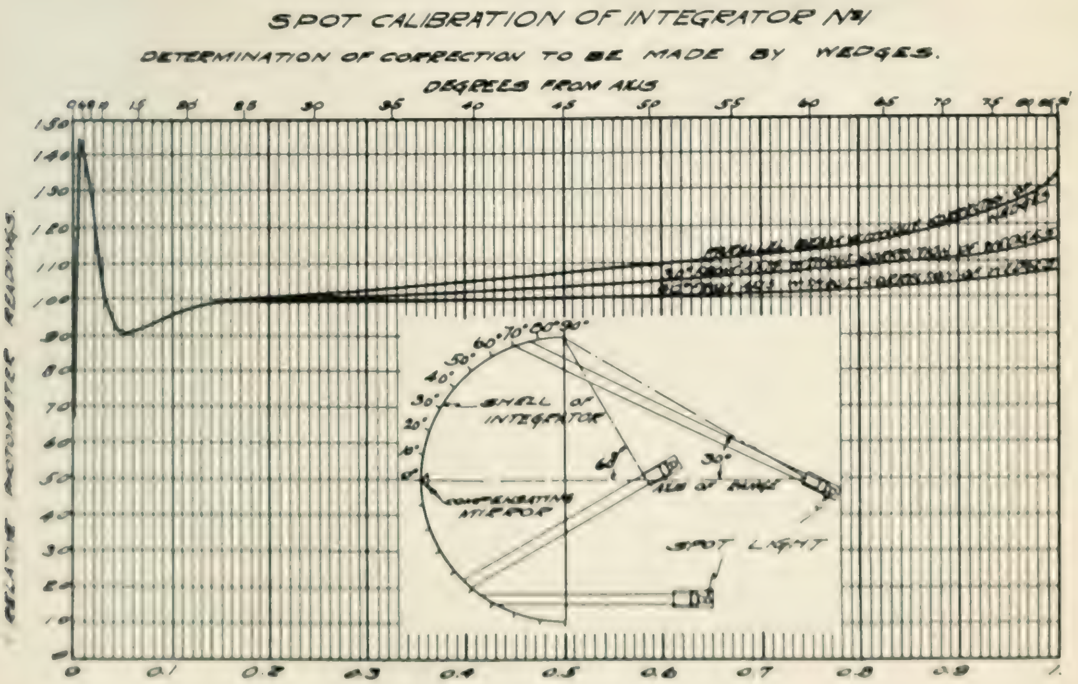
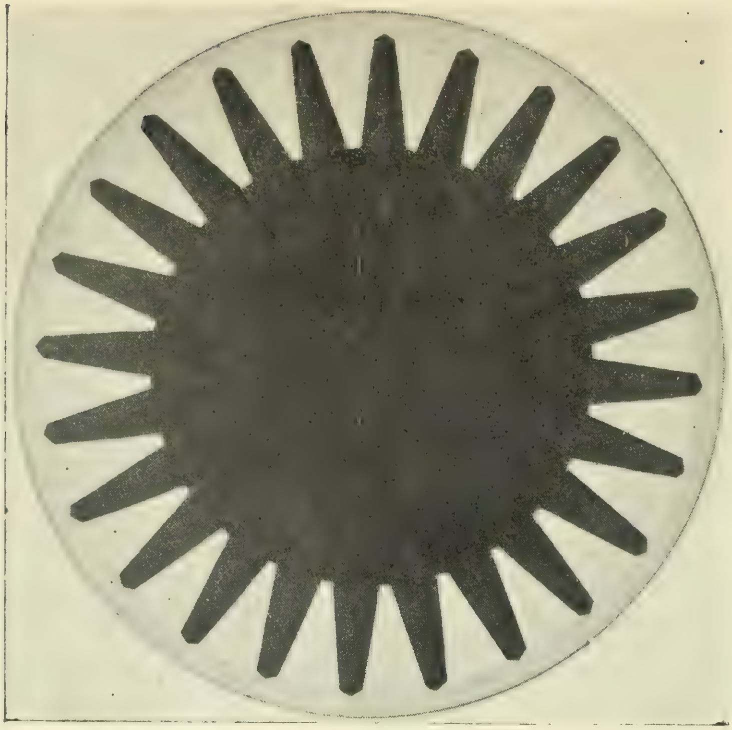


Fig. 6.—One-Half of the Indoor Searchlight Range in Operation.

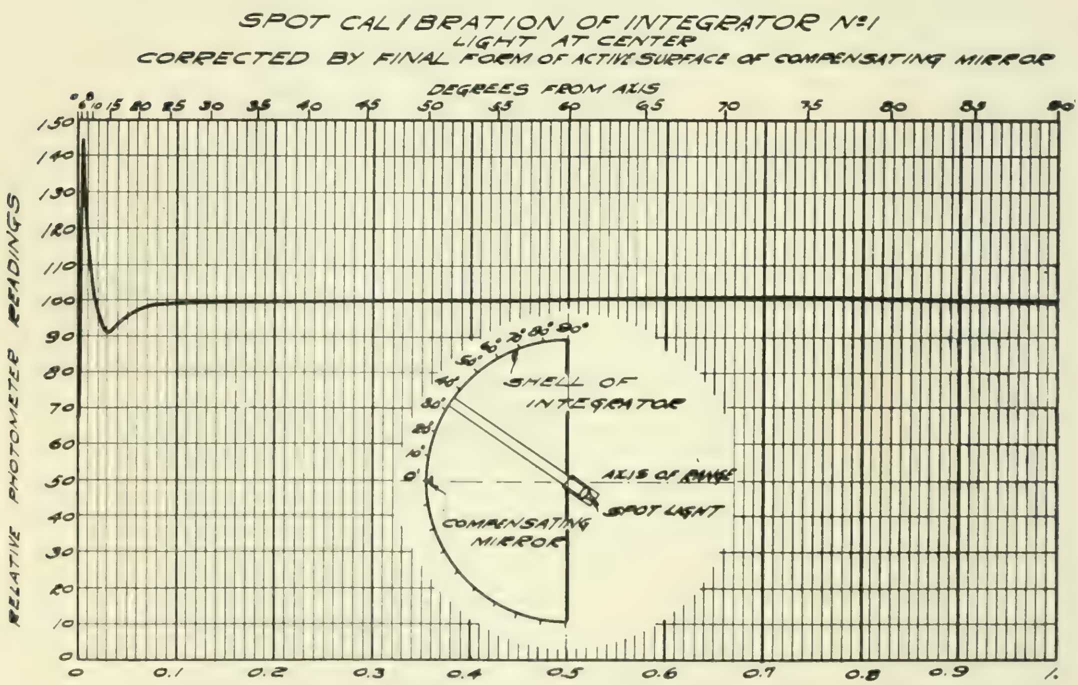
The rings of light on the curtains show how effectively stray light from the projector is trapped. During test work every precaution is taken to keep the air free from smoke or dust, but while the photograph was being taken, smoke was introduced into the beam and extra room lights were used to bring out the details of the black curtains and of the white focusing curtain on the right.



Plane Area of Opeating.

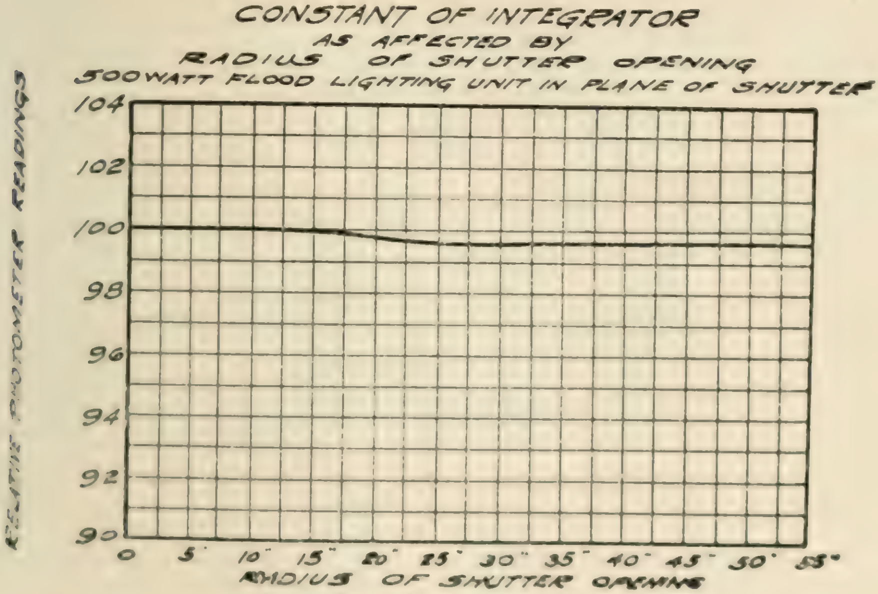


Compensating Mirror for Integrator No. 2.
Showing the form of star figure and the zone of clear glass where the silver has been removed.



Spherical Area of Intregrator.

sphere. An example will make this evident. In the analysis of the beam from a floodlighting unit the first setting is at 150 ft. with a shutter opening of 2.63 ft. radius. This opening subtends a total arc of 2°, as seen from the unit. The next position is at 131.4 ft. with the full shutter opening of 4.58 ft. In this position the edge of the hemisphere and not the shutter determines the angle which is 4° total arc. The shutter is left at full opening and the hemisphere placed successively at 87.6 ft. 65.6 ft. for arcs of 6° and 8°. If the integration is carried up to say 60° total arc, the distance from unit to the plane of the opening is 7.94 ft., and the distance must be accurately adjusted. In this particular case there is a geometric significance in the placing of the light center on the zero mark, because practically all the light at the edge of the hemisphere is direct radiation and the reflector plays little or no part at the edge of the 60° cone.



After the total flux has been measured up to angles 2°, 4°, 6°, etc., the differences between successive readings are tabulated and each divided by the proper zone constant, reducing the zone lumens to zone candles.

It will perhaps appear that the order of accuracy of beam intensities determined by this method will not be high, and such will doubtless be the case unless we take as our criterion the other usual test methods. A brief analysis will show why this is so.

There are two typical cases of photometry of a beam of light. One is the measurement of the steady, but streaked and unsymmetrical beam from an incandescent lamp, and the other is the measurement of the homogeneous but flickering and moving beam from an arc. Experience has shown that the readings in any given plane of an incandescent beam can rarely be checked, although the reading points may presumably be the same. The difficulty lies in the overlapping filament images that give the beam its mottled appearance. To determine the real average intensity in a given plane or zone would require an excessive number of test stations. The hemispherical integrator, on the other hand, is almost unaffected by the unevenness of the beam, and the integration of any zone should be better than the net accuracy of the usual number of accurate readings distributed over a very uneven field. An extreme example of this was encountered only a few weeks ago. An experimental reflector gave a wide angle beam with eight peaks 20° from the axis and evenly spaced in position. Several tests made with the integrator gave excellent agreement among themselves, and while this does not constitute a proof of accuracy, it is at least good evidence to that effect.

Regarding the photometry of arc searchlight beams, it may be of interest to know that at this laboratory thirty traverses are considered necessary for the determination of the beam intensity characteristic. Experience has shown that any number much less than this will not give data that can be checked. During one night's work, when working conditions were unusually favorable, twelve traverses were made on a certain searchlight. The beam lumens have been calculated for each traverse, and they give a probable error of 10.8 per cent. for one traverse. An almost equal number of photometer readings with the integrator in twelve sets of one hundred and forty readings each gives a probable error of 5.1 per cent. for each set. If we assume that both methods are free from constant errors, the integration method has a probable error one-half as large as the distribution method.

The integrators have been used only a few times for the determination of bare lamp efficiencies and reflector efficiencies, and no data can be given on the accuracy of this type of work. It should be noted that, in theory at least, it can be shown that, even in the case of an extremely unsymmetrical side lighting unit, the

instrument is free from error. As shown in a previous paper, there is every reason to expect that these instruments will be extremely useful in this class of work.

DISCUSSION.

S. L. E. ROSE: In some cases it is found desirable and necessary to measure beam candle-power by the point by point-method on small projectors and floodlights. The method described in this paper, viz. of using the hemispheres to obtain the lumens in various zones and then converting these values to zonal candles by means of constants gives the average candle-power curve of a beam of light which is preferable in most cases.

In cases where the point by point-method is necessary an arrangement has been devised wherby such readings can be made with the same photometer that is used on the hemisphere without moving it from its position. The compensating mirror is removed and in its place a metal tube is substituted which fits around the photometer test plate and is long enough to exclude from the test plate all light reflected from the inside surface of the hemisphere. The projector to be tested is placed on a turntable equipped with a protractor and an exploration of beam intensities may readily be made without disturbing the calibration of the hemisphere for its regular use.

Beam candle-power tests were recently made on an incandescent projector by these two methods and the two curves checked remarkably close throughont.

A PHOTOELECTRIC PHOTOMETER.*

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Abstract—This paper notes the difficulties which heretofore have prevented the use of the photoelectric cells in routine photometry. The use of a phermionic amplifier to increase current readings is suggested, also a filter to reduce the proportion of blue light and render the indications proportional to the photometric value. With such equipment, lamps are compared by varying their distances to the cell, until the deflection of the galvanometer is the same as that given by the standard lamp.

When light falls on the surface of an alkali metal, electrons are thrown off, the number liberated being proportional to the intensity of the light which strikes the metal. If an electric potential is supplied between the alkali metal and another electrode, with the alkali metal as cathode, the liberated electrons will therefore carry a current whose magnitude will be a measure of the intensity of the incident light. The photoelectric cell usually consists of a spherical glass bulb with an electrode placed as nearly as possible at its center. The bulb is highly evacuated, or filled to low pressure with an inert gas, and both the inner electrode and the inner surface of the bulb are coated, except for a small opening to admit the light, with a conducting layer of the distilled alkali metal. Either the outer surface or the inner electrode may then be used as cathode. A photoelectric cell made up in this manner responds to very faint illuminations, and has the advantage over the selenium cell of being practically instantaneous in its action. These characteristics have made it a valuable instrument for certain scientific purposes such as measuring the light from the stars and studying the energy in different parts of the spectrum.

It is at first sight surprising that no serious efforts have been made to apply the photoelectric cell to measurements of candlepower in industrial work. This may be accounted for by the fact that there are two essential difficulties which must be overcome before such an application of the instrument can be made. In

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

the first place the currents which pass through a photoelectric cell when illuminated to the extent customary in lamp photometry are of the order of only about 10^{-11} amperes, which is too small to be measured with an ordinary galvanometer. This makes necessary the use of some electrostatic method of detecting the current or the use of some method of magnifying the initial current. In the second place, the photoelectric cell has not the same relative sensitiveness in different parts of the spectrum as has the eye. Whereas the eye is most sensitive to yellow green light, the photoelectric cell is most sensitive to blue light, and is only slightly affected by red and yellow light. For this reason if a carbon and a tungsten lamp are of the same brightness as judged by the eye, the photoelectric cell will be affected considerably more strongly by the tungsten lamp because of its whiter color. It is necessary, therefore, to use in connection with the photoelectric cell an absorption screen which will correct for the selective action by radiation of short wave-length.

A customary method of increasing the current which passes through an illuminated photoelectric cell is to fill the cell with an inert gas at low pressure and apply across the tube a potential difference sufficiently great to produce ionization by collision. The current can thus be multiplied many fold. The formation of a hydride on the surface of the metal also increases greatly the photoelectric effect. The current as thus magnified can be readily measured by means of a portable electrometer of suitable design. Those who have used electrometers, however, will realize the difficulties which arise in warm, damp weather due to moist insulation. It seems almost impossible to avoid these troubles sufficiently to obtain in this manner reliable results in summer weather. For this reason I have found it advisable to magnify the photoelectric current still further by the introduction of a three electrode valve.

A diagrammatic sketch of the connections as thus used is shown in Fig. 1. The inner electrode C was used as the photosensitive cathode, while all the inner surface of the bulb, except for a small opening O acted as the anode A of the photoelectric cell. The cathode was connected directly to the grid G of the valve tube, and was shunted through a high resistance of about 1000 megohms to the negative terminal of the battery B_2. The grid

potential V_1 and the plate potential V_2 were adjusted in such a manner as to obtain a plate current which was of a magnitude easily measurable on the galvanometer M when the photoelectric cell was illuminated, and as small a current as possible when the cell was dark. For the particular three electrode valve employed the most effective grid voltage was -20, while the plate voltage varied from 95 to 110 according to the intensity of the illumination used. The plate current can conveniently be made as large as several milliamperes, but more satisfactory results were obtained when the maximum current was adjusted to about half a microampere. Since all the connections between the cathode C, the grid and the high resistance can be completely enclosed and protected from moisture, all difficulty with regard to insulation leak and the measurement of the photoelectric current can thus be overcome. The only precaution necessary is to use batteries B_1 and B_2 of as constant voltage as possible.

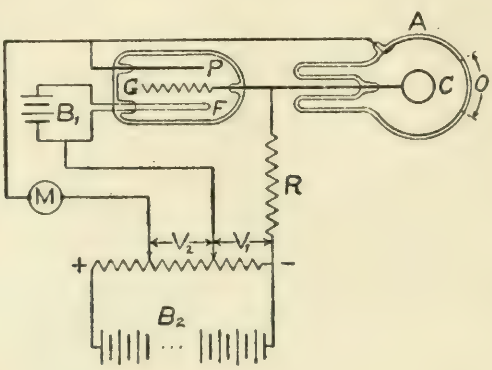

Fig. 1.

The color differences for which it is necessary to correct are the slight variations due to comparatively small changes in the temperature of the lamp filament. Unless caesium or rubidium is used for the photosensitive substance, it is impossible to duplicate the sensibility curve of the eye, since the other alkali metals are not sensitive to light in the extreme red. Sufficiently good results can be obtained, however, if only incandescent lamps near their normal operating temperature are to be measured, by the insertion of an absorption screen which will cut out the light of wave-length shorter than some certain value. If, for example, an unprotected photoelectric cell is used, since the maximum sensitiveness is in the blue, an increase in the temperature of the fila-

ment will produce a greater change in the photoelectric current than in the brightness of the lamp. On the other hand, if an absorption screen is inserted which permits only the red light to pass, the change in the photoelectric current will be less than the change in brightness. It is obvious that an absorption screen can be chosen to remove light shorter than some intermediate wavelength with the result that the change in the photoelectric current will be the same as the change in brightness. Experiment shows that if a potassium cell is used, a screen should be employed which transmits radiation longer than about 5300 A.° U. and absorbs the shorter wave-lengths. The selection of a suitable screen of this type is not at all difficult.

For many scientific purposes photoelectric cells using rubidium or caesium for the sensitive substance are desirable, because these cells give the greatest photoelectric current and are comparatively more sensitive to the longer wave-lengths than are cells using potassium or sodium. For industrial purposes, however, the low melting points of caesium and rubidium preclude their use, since the characteristics of the cells would change when the surface melts. For this reason potassium is the most satisfactory material to use. Its melting point is well above the maximum room temperature, and it is sufficiently sensitive to the action of red and yellow light to give measurable currents when the proper absorption screen is inserted.

If it were possible to use a high vacuum photoelectric cell the troublesome variations in the photoelectric current with changes in the voltage across the cell would be eliminated. Unfortunately in a good vacuum the vapor pressure of the potassium is sufficiently large to destroy rapidly the insulating properties of the glass. This makes it necessary to insert a certain amount of gas, and it is found that helium is satisfactory for the purpose. As mentioned above, this atmosphere serves the purpose also of magnifying the initial current by ionization, if a sufficiently large potential is applied to the tube.

A necessary precaution in the construction of a suitable photoelectric cell is that the bulb of the cell should be almost completely coated with a conducting layer of metal. If this is not done the insulated portions of the glass may collect charges which will modify the magnitude of the photoelectric current.

The characteristics of the three electrode valve are such that it is not practicable to calibrate a photoelectric photometer of this type permanently to read intensity of illumination. There are, however, a number of methods by which the instrument can be used to advantage. For example, in measuring horizontal candlepower a standard lamp at a fixed distance can be made to produce a certain deflection. The candlepower of other lamps can then be determined by measuring the distance from the photoelectric cell at which they will produce the same deflection.

For the intensity of illumination usually employed the plate current which is measured by the galvanometer M is approximately proportional to the square of the illumination. By help of this fact the photoelectric photometer may be used as a direct reading instrument in comparing lamps of about the same candlepower. If the galvanometer scale is divided according to this law, and if the reading is 100 per cent. when a standard lamp is used, the relative brightness of any other lamp can be read directly. This arrangement would be especially convenient where a number of lamps of the same rated candlepower are to be compared.

The same method of measurement can be used to advantage in determining the spherical power by means of an integrating sphere. The photoelectric cell with its orange screen may be placed at the opening in the sphere and be adjusted to give a deflection of 100 per cent. when a standard lamp is placed within the sphere. The relative total light emitted by any other lamp of about the same candlepower can then be read directly. Experiment has shown that it is not difficult by this means to compare the spherical candlepower of two similar lamps to within a probable error of 1/10 per cent.

Other electrical photometers, such as the selenium cell and the thermopile or bolometer with suitable absorption screens, have not been found adaptable to industrial photometry. The selenium cell, for the low illuminations which it is necessary to employ, is found to be slow in response and not very consistent in results. On the other hand, the thermopile and bolometer can hardly be made sensitive enough to respond to the illumination from lamps of low candlepower when a suitable absorption screen is employed. A satisfactory screen for use in connection with the

thermopile is also a serious consideration, since it is necessary to cut out all the infra red radiation. This problem is much simplified when the photoelectric cell is used, since this instrument is not affected by radiation of wave-length longer than that of visible light.

As compared with the optical methods of photometry, the photoelectric photometer has all the advantages of a deflection instrument over one which requires the judgment of small differences of degree. It is not only easier but it also requires less time to read a deflection than to make an accurate judgment of relative brightness. It is obvious that an instrument of this kind cannot entirely replace the visual photometer, since the eye is the final authority in estimating illumination. But when the photoelectric photometer has been adjusted to make true measurements of intensity of illumination, it offers the advantages of greater speed, less fatigue and higher accuracy where a large number of measurements on similar lamps are to be made.

GLARE MEASUREMENTS.*

BY WARD HARRISON.

Synopsis: Data are presented showing the range of agreement in opinion among a number of observers as to the glare from bare lamps and other more diffuse light sources, in comparison with a reference source of variable intensity. The practicability of a rough classification of lighting installations into groups according to the sensation of glare as registered by a small instrument based on this method of comparison, is discussed.

A few years ago the writer had occasion to make a very simple demonstration involving impressions of different individuals as to glare. The set-up consisted merely of a row of ten or twelve light sources of various candlepower, some bare lamps, some frosted lamps, and some in globes or reflectors. All were lighted and the observer was asked to state which of the sources he deemed most objctionable from the standpoint of glare. The source named was then extinguishd and he was requested to point out the most glaring of those which remained, and so on until but one was left burning. The unexpected feature of this investigation was that practically all of the observers asked to have the lamps turned out in precisely the same order; in fact, there were but three or four cases among fifteen observers where a difference of opinion existed as to the relative standing of any two light sources. The writer sought for some time to find a basis upon which this unusual agreement might be explained, and finally ventured the hypothesis that the human eye might of necessity have acquired in a limited degree the ability to equate the relative discomfort caused by two light sources in a manner analogous perhaps in its ability to determine equality of brightness. To make some test of this hypothesis the following series of experiments was planned.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

APPARATUS AND TEST METHOD.

Two similar boxes painted flat black, shown in Fig. 1 were placed adjacent to each other at such a height that the units to be tested were suspended approximately 5 ft. above the eye level and 15 ft. from the observer. One box held the light sources to be tested and the other contained a reference source. This reference source was a disk of ground glass 3½ in. in diameter mounted flush with the back of the box and illuminated by a lamp placed behind it. The variation of intensity of this source was controlled by the observer through the use of a rheostat in series with the lamp. In order to overcome the color change that would necessarily take place if the candlepower of a lamp were varied through a wide range, seven lamps between 50 and 500 watts were used. These lamps were mounted on a board which could be slid through guides to bring each lamp in turn back of the glass disk. Within the permissible range of color variation each lamp overlapped the next smaller and next larger so that in attempting to equal the glare from the test lamps the observer was not unduly limited in his range of convenient variation of the reference source brightness.

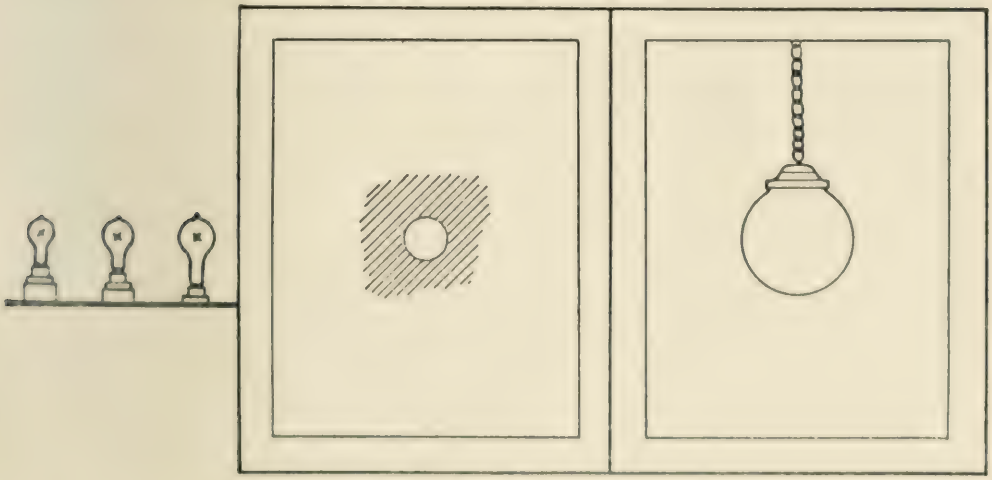

Fig. 1.

During preliminary work it was found desirable to supply some illumination on the interior of the box containing the reference source. Enough light was supplied to give the interior of the box a brightness of about 0.6 millilambert (0.5 apparent lumen per sq. ft.). This brightness was maintained throughout the tests.

The light sources tested and their candlepowers are shown in Table 1. It will be noted that some of the lamps were not operated at exactly the proper voltage.

TABLE I.

LAMPS AND EQUIPMENT TESTED.[1]

	Candlepower	Bulb diameter	Kind of bulb	Approximate brightness Cp. per sq. in.	Size of lamps Watts
1.	36.5	2½	Clear	3,000	50
2.	99.0	3⅛	Clear	3,000	100
3.	177.0	3⅛	Clear	3,000	150
4.	212.0	3¾	Clear	3,000	200
5.	176.0	3¾	All frosted	125	200
6.	28.3	2½	Opalized	5	50
7.	196.0	3¾	Opalized	16	200
8.	28.5	10-inch opal ball	———	0.4	50
9.	166.0	10-inch opal ball	———	2	200

Ten observers were chosen without regard to any previous thought or experience they might have had regarding glare. Before an observer made any settings of the reference source the hypothesis in the introduction was presented to him. The observers were cautioned not to attempt to make a comparison simply by means of equating the brightness of the reference source with that of the test lamp, or by color matching. After each setting of the reference standard its candlepower was altered by means of an auxiliary resistance out of sight of the observer so that in future readings he would not tend simply to duplicate the setting of his rheostat. It was found that individual settings by an observer deviated from the mean of three or more settings by an average of about 10 per cent. and the mean of three settings was taken to constitute one reading. In every case readings on all nine test sources were taken at one sitting. A second set of readings was taken three or four days later by all observers. One set of readings ordinarily required about forty-five minutes.

Fig. 2 showing the results of these observations on a 200-watt lamp in a 10 in. opal ball is typical. The results of the first day's reading are shown as a circle (o) and the second as a cross (x).

[1] All lamps were of the gas-filled type.

The results are plotted to a logarithmic scale and the logarithmic mean of all observations is shown by the broken line.

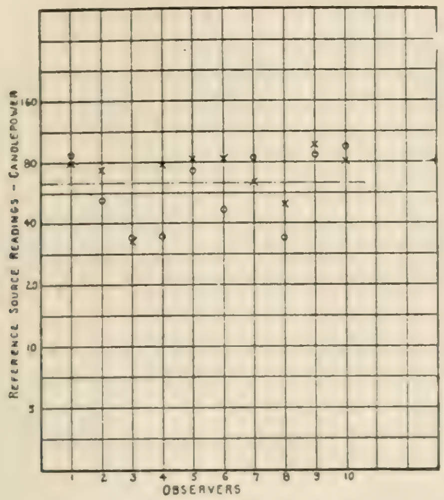

Fig. 1.

Table 2 shows the average of the readings of each of the ten observers for the two days and their individual deviations from the mean. It will be noted that the widest deviation occurred in the case of the 50-watt lamp in the 10 in. opal ball. As a matter of fact, the brightness of this unit was so low that it could by no means be classed as uncomfortable, and in attempting to make settings a decided lack of assurance on the part of observers was noted.

Several observers were asked to make the usual comparison between the test and reference source in a slightly different way. Settings were made with the interior of the reference source box at two brightness levels, one many times as great as the other. When the brightness of the interior of the reference source box was increased ten times it was found necessary to increase the reference source brightness approximately 80 per cent. (see Table 3) in order to maintain apparent equality of glare with a specific test source in the adjacent box. It is of interest to note that data presented by Dr. Nutting (TRANSACTIONS of the I. E. S. Vol. XI, page 943) although obtained in an entirely different manner indicated that increasing the general level of brightness ten times permitted of increasing the brightness of a light source in the field by about 105 per cent.

TABLE 2.

AVERAGE OF TWO SETS OF READINGS BY TEN OBSERVERS.

Observer	36.5 s. c. p. clear bulb lamp	99 s. c. p. clear bulb lamp	177 s. c. p. clear bulb lamp	212 s. c. p. clear bulb lamp	28.3 s. c. p. opalized bulb lamp	196 s. c. p. opalized bulb lamp	28.5 s. c, p. 10 in. opal ball	166 s. c. p. 10 in. opal ball	176 s. c. p. all frost bulb
1	57.5	135.0	236.0	293.0	26.2	141.8	10.2	82.5	141.0
2	51.7	99.5	157.0	144.0	35.2	127.5	18.3	61.6	111.0
3	73.5	116.0	195.3	165.5	25.5	89.0	9.4	33.7	79.0
4	47.3	86.5	185.0	241.0	36.0	129.0	6.2	51.5	95.0
5	73.1	100.1	186.0	206.0	30.8	109.5	13.2	77.0	81.8
6	57.4	100.1	139.0	167.0	29.2	184.0	7.8	62.0	64.1
7	154.0	178.0	238.0	261.0	37.6	133.0	10.4	73.0	115.7
8	107.0	154.0	245.0	272.0	28.6	152.0	8.0	40.8	131.0
9	38.2	72.0	96.7	114.5	37.0	131.0	23.9	91.5	120.0
10	56.2	138.0	218.0	257.0	45.5	160.0	21.5	87.6	163.0
Average	66.0	113.9	183.0	204.0	32.6	133.0	11.65	63.0	106.4

PER CENT. DEVIATION FROM AVERAGE.

Observer	36.5 s. c. p. clear bulb lamp	99 s. c. p. clear bulb lamp	177 s. c. p. clear bulb lamp	212 s. c. p. clear bulb lamp	28.3 s. c. p. opalized bulb lamp	196 s. c. p. opalized bulb lamp	28.5 s. c, p. 10 in. opal ball	166 s. c. p. 10 in. opal ball	176 s. c. p. all frost bulb
1	12.8	18.8	29.0	43.8	19.5	6.6	12.5	31.0	32.0
2	21.5	12.5	14.2	29.5	8.0	4.2	57.0	2.3	4.0
3	11.2	2.0	6.5	18.9	21.7	33.0	19.5	46.5	25.8
4	29.5	24.0	1.0	18.1	10.2	3.0	46.9	18.3	10.9
5	11.0	12.0	1.5	1.0	5.5	17.6	13.2	22.1	23.2
6	13.0	12.0	24.0	18.0	10.5	38.2	33.0	1.6	39.7
7	133.0	56.5	30.0	28.0	15.2	0.0	10.7	16.0	8.7
8	62.0	35.2	34.0	33.5	12.3	14.2	31.5	35.1	23.0
9	42.0	36.7	47.1	43.9	13.5	1.5	105.0	45.0	12.8
10	14.8	21.0	19.0	26.0	39.8	20.1	85.0	39.0	53.0
Average	35.1	23.1	20.6	26.1	15.6	13.8	41.4	25:7	23.3

The individual observations recorded in the foregoing tables may at first sight appear to be too far apart to permit any conclusions being drawn but at the same time it must be remembered that an order of precision such as obtains in ordinary measurements of light intensity or even in heterochromatic photometry was scarcely to be expected, in fact, if the observers were able to classify the sources into three or four groups with some uniformity of opinion, that would be about all one could reasonably hope for. To try out the possibility of such groupings the total range of values obtained was arbitrarily subdivided into four parts as follows:

Group A	0—25
Group B	25—50
Group C	50—100
Group D	100—and above

If one were to attempt to assign ratings to the various light sources for the particular conditions of background, mounting height, etc., which obtained in the test, then those read below 25 might be classified as excellent from the standpoint of glare; 25—50, good; 50—100 just passable; 100 and above, unsuited for general use. In Table 4 the letters A, B, C, and D indicating the four groups respectively have been substituted for the figures in Table 2. It will be noted that with a single exception differences in rating by this method would not in any case extend over more than two groups, in other words, a light source rated excellent by one observer would be sure to be classed either as "excellent" or as "good" by all of the others. No one would condemn it or rate it as low as "just passable."

Likewise, a source condemned by one observer would either be condemned or rated not better than "just passable" by all the others. There is no question that an instrument of this order of precision for measuring glare from light sources would be of very considerable value in many instances such, for example, as in the administration of lighting codes. It appears that the development of a portable instrument along the lines suggested by the foregoing experiments is not entirely out of the question.

It is generally accepted that for a fixed position of light source with respect to the eye the degree of glare experienced is a function of (1) brightness of the source—candlepower per unit area;

(2) total flux of light directed toward the eye from the source—candlepower in the direction of the eye; and (3) contrast in brightness between the light source and its background. Authorities differ greatly as to the relative weights to be assigned to these three quantities. It is interesting to note that in the opinion of the observers in these experiments a clear bulb, gas filled lamp of approximately 100-candlepower was not considered so objectionable as a lamp of double the candlepower in an opalized bulb although the brightness of the former was of the order of 3,000-candlepower per square inch and of the latter but 16 candlepower per square inch.

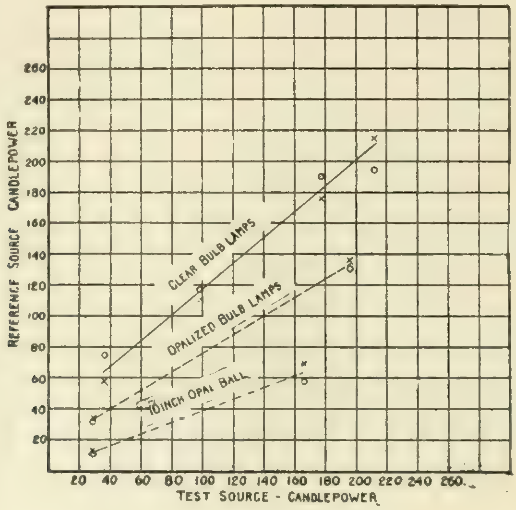

Fig. 3.

Viewing the matter from another standpoint we find that the improvement effected by changing from a clear bulb 200-watt lamp to an opalized bulb is of the same order of magnitude as the change from an opal bulb to a 10 in. ball. All of these results point to the total light flux which reaches the eye from a source as being the most important single factor in the production of glare. The data also tend to support the opinion, frequently advanced, that for bare lamps viewed at a considerable distance from the eye it is more reasonable to express the brilliancy of the source in terms of total candlepower emitted from an area of appreciable size such for example as from 1 sq. in. rather than simply in terms of absolute brightness, that is, candlepower per unit of filament surface.

On the other hand, it should be noted that, candlepower for candlepower, a frosted lamp and an opalized bulb lamp were placed in the same class although the maximum brightness of the latter was about eight times that of the former; in this case the sharp contrast between the periphery of the opal bulb and its dark background was no doubt a large factor in the decision.

Some surprise has been expressed that the relatively low average readings obtained for the clear bulb 50-watt gas-filled lamp in comparison with other units tested, however, it must be remembered that the height of the source and its distance from the eye were both much greater in this test than one would ordinarily find in the use of this size of lamp.

In Fig. 3 the average values obtained for the nine units tested are plotted graphically. The interesting feature of this chart is that the values for all of the clear bulb lamps tested fall practically in a straight line, that is, the glare rating increased directly with the candlepower. It would have been interesting to learn whether the same rule appeared to hold for the other light sources but unfortunately not more than two units of any other type were included in this series of tests and time did not permit of a repetition of the experiments. A few readings by a smaller number of observers indicated, however, that a further investigation of the opal bulb or opal ball units would result in a straight line curve for these sources also, and the probability of such a result has been indicated by dotted lines.

TABLE 3.

Observer	Readings: Background Brightness 0.1 Mililambert*	Background Brightness 1.0 Mililambert*	Ratio
1.	34.6	65.0	1.88
2.	19.3	34.0	1.76
3.	37.0	63.0	1.60
4.	16.5	32.6	1.98

* Approximate values.

TABLE 4.

Classification of Sources Tested.

Observer	36.5 s. c. p. clear bulb lamp	99 s. c. p. clear bulb lamp	177 s. c. p. clear bulb lamp	212 s. c. p. clear bulb lamp	28.3 s. c. p. opalized bulb lamp	196 s. c. p. opalized bulb lamp	28.5 s. c. p. 10 in. opal ball	166 s. c. p. 10 in. opal ball	176 s. c. p. all frost bulb
1	C	D	D	D	B	D	A	C	D
2	C	C	D	D	B	D	A	C	D
3	C	D	D	D	B	C	A	B	C
4	B	C	D	D	B	D	A	C	C
5	C	C - D	D	D	B	D	A	C	C
6	C	C - D	D	D	B	D	A	C	C
7	D	D	D	D	B	D	A	C	D
8	D	D	D	D	B	D	A	B	D
9	B	C	C	D	B	D	A	C	D
10	C	D	D	D	B	D	A	C	D
Average	C	D	D	D	B	D	A	C	D

In closing, the author desires to express his appreciation of the valuable assistance rendered by Mr. E. W. Commery in conducting the tests which have been described.

DISCUSSIONS.

J. R. CRAVATH: The methods that have been proposed for glare testing have so far been directed to three rather distinctly different objects. We have a class of tests for eye fatigue after long periods of work under various conditions of glare of which the Ferree method which has been extensively discussed before this society is perhaps the best example, at least it has been the most thoroughly tried. Then we have a class of tests which direct themselves to determining the actual interference with vision under given conditions of glare. In this class those originated and conducted by Mr. A. J. Sweet and later checked by Mr. Preston S. Millar are the most prominent examples. The one we are considering now, Mr. Harrison's, is what might be termed a snap judgment test. It may be none the less valuable but it must be recognized as such. Dr. Nutting gave us some laboratory tests at our 1916 convention which I would classify in the same class, that is momentary judgments as against eye fatigue or interference with vision. It seems to me Mr. Harrison has hit on something here that may be of considerable practical value. It will be very interesting if future investigators can determine what relation there is between these three phases of glare. It will take considerable investigation to find out, but it is certainly something that will be worth investigating. The determinations by this test are certainly much less laborious than those in the other classes, in fact, it may be that this method bears about the same relation to more exact methods that have been proposed as a foot candle meter does to the more elaborate photometer, namely a good short cut with a very practical application.

MR. SWEET: I am very happy indeed to note that the author of the paper makes very clear what he means by the use of the word glare in connection with this investigation, namely, what I think might perhaps more descriptively be termed immediate ocular discomfort. He makes very clear that these measurements are not measurements of the depression of the visual function result-

ing from the disturbance. I think we must be very careful indeed in drawing any conclusions from results of discomfort as to either the interference with vision or as to the degree of fatigue, of ocular fatigue and of, ultimately, eye strain which may be produced by those conditions. We all recognize how poor a guide the intensity of a beam is as to the degree of injury produced. In the same way I think that the degree of ocular discomfort is a very poor guide indeed as to the seriousness in disturbing vision either immediate or in bringing about ultimate conditions of fatigue or eye strain. We are, however, certainly very interested indeed in avoiding conditions which involve immediate ocular discomfort. The tentative conclusions of the author from the results are especially interesting as indicating the importance of the total light flux as well as intrinsic brilliancy. That is a feature which perhaps we have not, at least I for one have not considered to enter so greatly into immediate ocular discomfort. On the other hand, my own work has indicated that intrinsic brilliancy has a very negligible effect in decreasing the capacity of the eye to see and that the particular quantity that does affect the capacity of the eye to see is the light flux, the angle being fixed for the matter in question.

It is also very interesting to note the apparent straight line relationship indicated in Figure 3 and to compare that with other results on the decrease in the capacity of the eye to see indicating straight line relationship under logarithmic rather than straight rectilinear plotting. I feel that this paper is a very valuable one as on one hand checking and corroborating certain things we have generally believed but which we all recognize today to be inadequate for a conclusive viewpoint and offering certain new very suggestive indications of the line to which we may look for further advance in knowledge.

F. C. Caldwell: We have made some tests on different phases of illumination in this same manner, that is, by obtaining the judgment of a considerable number of persons as to their preferences with regard to lighting conditions. The results obtained have seemed to indicate a good deal of value in this general method; a very fair degree of agreement among different observers uneducated from the point of view of illumination is obtain-

able. I am also glad to see the emphasis that this work puts upon the importance of the total flux as an element in glare. I have known men who had given considerable thought to illumination problems to insist that the glare experienced from a light would be the same whether it was 10 feet or 100 feet away, because the brightness was the same.

Mr. Stickney: Mr. President, I ran into this glare problem first when we were working on Mr. Mark's Committee on Lighting Legislation. We felt a very strong need of a glare specification, and to my mind there is today a real need for a system of glare measurement. We must be able to find a way of drawing a line between a safe and an unsafe condition that will be as near fair as we can make it and a practical thing for n inspector who is going around inspecting installations and so that the manufacturer's engineer who is left to determine what sort of an installation shall be put in, can find a way of eliminating this glare on a basis that does not require him to go to far to one extreme or the other. Of course we know well enough that certain installations are safe and certain installations are unsafe, but in the codes and the insurance companies' specifications we must draw a fair line and a line that can be drawn to some extent by an amature so that we can treat all illuminants fairly and all classes of installations fairly.

FACTORY LIGHTING—A CENTRAL STATION PROBLEM.*

BY O. R. HOGUE AND J. J. KIRK.

Probably no other single lighting subject has received as much recent attention from the Society at large and from the technical press as has that of factory lighting. It is not the purpose of this paper to go into the technical details of scientific illumination, as qualified engineers have fully covered the subject. Our aim is, rather, to indicate the experience of the Commonwealth Edison Company in an extensive campaign for better industrial lighting.

To the Illuminating Engineering Society is due the credit for first fostering the idea of better lighting in industrial plants. Many years of effort on the part of the Society and its individual members have shown tangible results in the adoption of lighting codes by a number of the states. To merely have a code adopted has not been the single aim of the Society, but persistent endeavor has been made to have the new codes as they are adopted reflect present practices of good lighting, as is evident from a comparison of the recent codes with the earlier ones.

A great deal of work has been done to educate the several reflector manufacturing companies and central stations to the value of good industrial lighting, but as yet the real object has not been attained—we have failed to carry this educational work to the average plant owner, who in the final analysis has the sole power to improve lighting conditions.

Impetus was given to better lighting by the standardization of lamps by lamp manufacturers, which has been furthered by a combined effort of the lamp manufacturers and reflector manufacturers in the adoption of a standard reflector. This standardization has made it possible for those who are called on to make recommendations to agree on types of equipment, and thus avoid confusing the customer by a multiplicity of equipment. The con-

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

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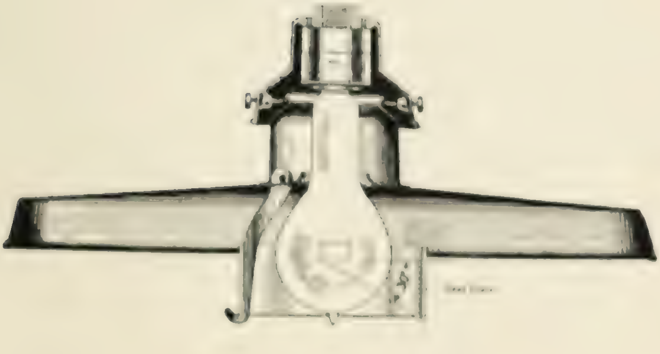
Opal Lamp Cap used with Dome Reflector

R-L-M Standard



fidence of the customer is thereby inspired and progress, which is dependent upon sales effort, made easier.

The central station companies in general have been the ones who have failed primarily to "carry on," this failure on their part being due to a lack of appreciation of the value and extent of this business.

To demonstrate what can be done to consistently improve lighting conditions, it is only necessary to compare intensity and other values given in the paper on "Factory Lighting" by O. R. Hogue and A. O. Dicker, presented before this Society at the Cleveland Convention in 1914, with the values given in this paper.

In Table No. 1 are data on a number of the larger installations made by the Commonwealth Edison Company during the past year, which will serve to show the tendency toward improvement in artificial lighting. It will be noted that the average intensities are more than double those in the installations listed in the former paper. Very little local lighting is used, and such local lighting in all excepting one case is a remnant of the old lighting, and was not recommended by the central station engineers. Of course we recognize that some local lighting is needed, but it is our aim to reduce this to a minimum.

Where local lighting is needed at intervals, it is suggested that wall receptacles be provided, and that extension cords be checked in and out of tool room just like a special tool. In this way the superintendent is given a chance to control its use and to prevent its becoming a permanent part of the lighting arrangement.

To show the value to the central stations, we have included data on income. In every case the new installation resulted in an increased monthly bill, although few were new customers. This is the sort of business that is most profitable, in that it adds no cost to metering and billing, and but slightly to the cost of service. Since there is always some other lighting or power consuming device in use, it is difficult to get an accurate figure on income, but the amounts given are the result of careful study of the customers' accounts before and after the new system was installed.

This indicates conclusively that illuminating engineering service not only benefits the customer, but renders his account more profitable to the lighting company.

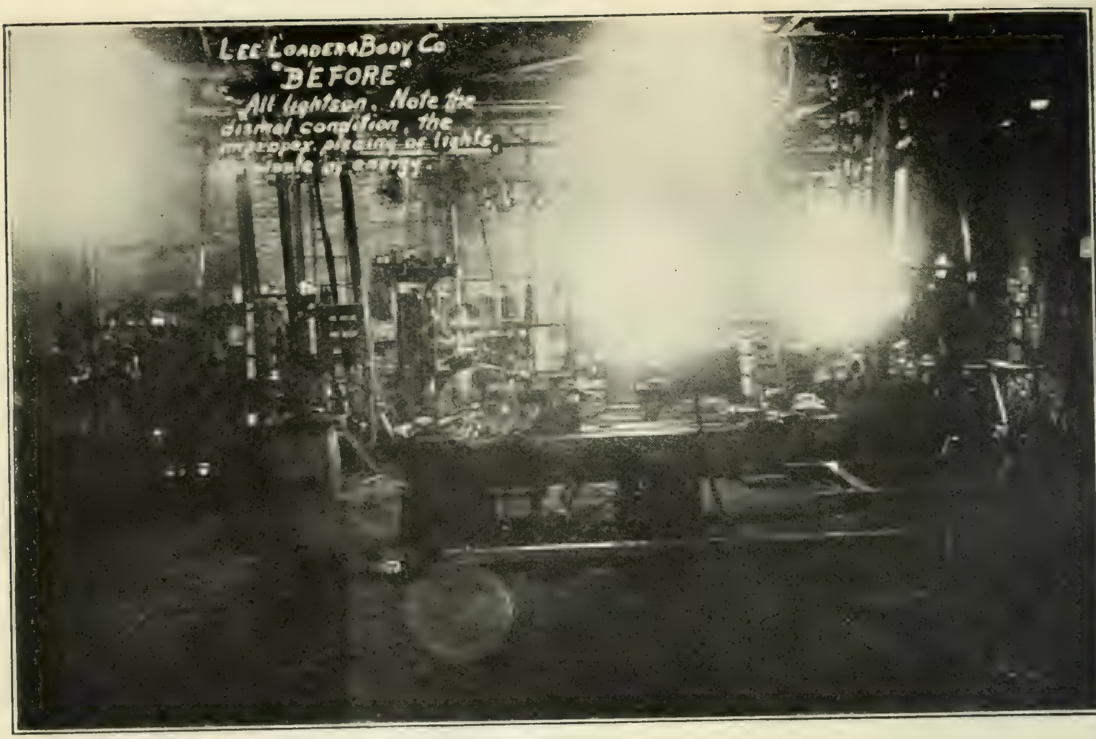
TABLE I.

No.	Class of business	Kind of work	Supplementary local ltg.	Units				Total kw.	Ft. above floor	Aver. foot-candls.	Estimated monthly bill for current	Estimated increase in per cent.
				60 w.	200 w.	300 w.	400 or 500 w					
1	Glove mfg	Bench	No	—	19	—	—	3.8	8½	8.5	16.50	New
2	Mach. shop	Screw mchy	No	—	29	—	—	5.8	9	10.0	64.00	New
3	Mach. shop	Mach. and bench	No	—	70	11	—	17.3	9	9.5	85.00	466
4	Boiler shop	Floor	No	—	—	11	—	3.3	12	10.0	18.00	New
5	Mach. shop	Mach. and bench	Some	—	49	—	—	9.8	8	6.0	50.00	400
6	Mach. shop	Mach. and bench	No	—	20	7	2	7.0	8 & 11	11.0	35.00	133
7	Awning mfg	Cut and sew	Some	—	14	10	—	6.0	8 & 10	6.0	35.00	200
8	Oven mfg	Floor and bench	Some	—	—	18	—	5.4	10	6.0	22.50	200
9	Tailor shop	Cut and sew	Some	—	12	—	—	2.4	8	10.0	20.00	New
10	Tailor supl	Table	No	—	—	14	—	4.2	9½	10.0	15.00	New
11	Weighing mchy	Mach. and bench	Some	—	34	—	—	6.8	8½	6.0	35.00	250
12	Foundry	Floor and bench	No	—	—	—	44	22.0	16	6.0	180.00	New
13	Foundry	Floor and bench	No	—	13	5	—	4.1	11	5.5	15.00	New
14	Cork mfg	Mach. and bench	No	—	—	14	—	4.2	10½	11.0	10.00	233
15	Furniture	Floor	No	—	27	—	—	5.4	8½	5.5	30.00	New
16	Electrotypes	Mach. and bench	Some	—	57	1	—	11.7	8½	9.5	70.00	366
17	Candy mfg	Bench	No	—	—	40	—	12.0	10½	6.0	65.00	1200
18	Paper boxes	Mach	No	—	86	1	—	17.5	8½	8.0	110.00	120
19	Fdy. and mchy	Floor and bench	No	—	—	—	21	9.9	10&14	7.0	75.00	650
20	Iron and steel	Floor and bench	No	—	10	5	2	4.5	8 & 15	6.5	30.00	New
21	Tool mfg	Mach. and bench	Some	—	—	55	—	16.5	10	9.0	100.00	300
22	Elec. controller	Mach. and bench	No	—	32	8	—	8.8	9	6.0	30.00	500
23	Wagons and autos	Floor and bench	No	—	16	—	—	3.2	9	5.0	18.00	46
24	Auto bodies	Floor and bench	No	—	—	27	—	8.1	10	12.0	60.00	300
25	Motor trucks	Mach. and bench	Some	10	28	—	—	7.2	9	8.0	40.00	166

48c


Foote Bros. "BEFORE"
All lights on. Note the few "high spots" of illumination, with midnight blackness surrounding them on all sides - typical of this class of lighting.


Foote Bros. "AFTER"
Note the high degree of uniformity for the wide spacing of units. Note the cheerfulness and utilization of every foot of floor space.


Lee Loader & Body Co
"BEFORE"
All lights on. Note the
dismal condition, the
improper placing of lights,


Lee Loader & Body Co. "AFTER"
Note the accurate control of generated
flux, the high average intensity and uni-
formity, and the splendid conditions
for riveting and lay-out work.

48 B.


FOOTE BROS. "BEFORE"
Note the extreme and blinding contrasts.
Note the difficulties confronting the night shift or overtime workers.


FOOTE BROS. "AFTER"
All milling machine graduations in plain sight, no shadows beneath overhang, due to cross lighting.


Rankin - Publishers "BEFORE"
(Floor above shown on opposite page)
Note wasted light on ceiling and darkness of working plane. Note gloomy conditions and congested lighting equipment.


AFTER

TABLE II.

Month	No. of units 200 w or less	No. of units 300 w.	No. of units 400 & 500 w.	No of units on rental basis	No. of units on sale basis	Total units	Aver. watts per unit	Total kw. connected	Est. monthly current cost	Min. foot-candles	Max. foot-candles	Aver. foot-candles	Aver. burning hours
August	296	44	14	140	214	354	192	68.22	245.35	3.0	9.0	5.1	4.5
September	601	54	7	340	322	662	192	127.00	687.30	2.0	12.5	6.4	5.3
October	850	134	2	789	197	986	191	188.73	985.10	3.0	15.0	6.3	4.7
November	691	138	15	475	369	844	214	181.06	876.17	3.0	12.0	6.6	5.0
December	592	73	61	515	211	726	210	152.11	943.00	4.0	15.0	6.7	5.2
January	1,033	146	42	786	435	1,221	228	278.30	1,634.00	3.0	11.0	6.0	6.0
February	644	123	5	642	130	772	207	159.50	932.00	3.0	14.0	6.1	6.0
March	573	59	11	594	49	643	204	131.20	730.25	4.0	10.0	6.0	5.0
April	846	85	8	572	357	939	213	200.30	1,285.17	3.0	12.0	5.9	5.1
May	655	50	0	472	233	705	191	134.68	902.78	3.0	18.0	5.9	4.8
June	958	28	0	347	639	986	212	210.80	1,078.68	3.0	11.0	4.9	4.7
July	801	40	0	709	133	842	180	128.30	667.16	3.0	13.0	3.7	4.0

The accompanying illustrations showing "Before" and "After" photographs of installations which we have made will help to show the change effected by our efforts.

Table No. II shows the business secured during the different months of the year. It will be noted that during those months which have the greatest amount of darkness, the average watts per unit are more than 200, and the average foot-candle intensity was over 6, indicating that industrial lighting is a seasonable business.

If the efforts of the Society to promote good practice are to meet with tangible results, they must be supported by active selling campaigns. The central stations, through their present contact with the customer, are in a better position to push industrial lighting than anyone else. It has been the experience of those who have actively engaged in this work that the entire time of men with special illuminating engineering training must be given to the work, if any real progress is to be made.

Although the services of our engineers are always available to architects and owners who wish advice as to the lighting of a new building, our field, as always, has been the established institutions with inadequate lighting. On this account we have the primary difficulty of convincing the customer that a change will prove profitable to him, and this requires a large amount of educational work. Next, he must be shown that the installation proposed is not unreasonable and that the company is not merely trying to get a big income at his expense. As a rule, we must convince him that the drop cord is poor economy for general lighting. Then, having sold the idea and the lay-out, we come to the task of selling the installation, and in this we often fail, for the small contractor, uncertain of his costs at best, and willing to hold profits to a minimum to keep his men working, is very likely to underbid us. However, as we furnish blue prints and specifications for each job, if the installation is made along the lines of our recommendations, we do not count the labor lost, for we have made a convert to good lighting and incidentally added a good load to our lines.

One sales point which we have found very effective, and which may prove of value to someone, is the figuring of the installation

down to unit costs. The total price for the job or for the operation of the proposed system may be high enough to discourage the prospect, but if it is figured on a basis of cost per square foot, and compared with his rental charge, or as cost per employee per month, and compared with the pay-roll, it assumes relatively minor importance.

Our rental and maintenance proposition for factory lighting has met with very gratifying results, appealing to the large as well as to the small plant. In this connection, we feel that the maintenance is of great importance. Not only do we give the customer a good installation, but we keep it efficient during the two-year period of the contract, and after that we aim to continue maintenance even though the equipment then belongs to the customer.

It has been found by experience that regular cleaning periods must be established, the frequency depending upon the character of the factory or shop; but in no case exceeding 30 days. Since this company uses a lock socket on all its equipment, it has complete control of the lamps, and after the equipment is turned over to the customer he is in a position to place the maintenance in the hands of one man, who should have entire charge of lamp renewals. This method not only prevents the theft of lamps, but also prevents the misuse of equipment by the installation of lamps of wrong sizes.

In order to raise the standard of lighting and induce plant owners to install systems with high intensities, it was necessary that we have data in the way of actual figures. With this end in view we selected a number of industrial plants where accurate cost records were kept and obtained permission to make a test. First a month's run was made with the old lighting system in use. Then a complete lighting system was laid out and installed by and at the expense of the company, and another month's test made. Finally, with a return to the original conditions, a third month's test was made. The results obtained were highly gratifying and in every case the customer was anxious to retain the new installation. In a number of cases we were not even permitted to go back to the old lighting for the third month's test, for the customer realized that it would mean actual financial loss to him. In making these installations we used so-called triple intensities;

that is, about three times the intensity ordinarily recommended, and although few installations are now made with that high a standard, still the average has been very materially raised.

The figures in Table III show the advantage obtained by increasing from the ordinary low standard to a moderate intensity, and also the still further advantage of increasing to a real production intensity. With such facts before us, it seems certain that in productive intensities we have the greatest possibility of service to industry, and wide adoption of such intensities, is only a matter of getting the truth before the responsible executives.

This opportunity is taken to call the attention of the members of this Society to the industrial exhibit, exemplifying the advantages of good lighting, now being conducted by the Commonwealth Edison Company at the electrical show. This exhibit consists of two shops, practically identical in size and equipment. One is known as "The Dismal Shop," and the other as "The New Shop."

In "The Dismal Shop" the lighting arrangement consists of local drop cords. The intensity on the work is fairly good, whereas the room and surroundings are in comparative darkness.

In "The New Shop" the general lighting with productive intensities has been provided.

Since both shops are in full operation, an opportunity is given to make a quick and convincing comparison of the two systems. It is the aim of this exhibit to bring home to the factory manager the value to him of proper lighting.

At the conclusion of the show this exhibit will be moved to space on the main floor of the Edison Building and there used as a permanent part of the campaign for better industrial lighting.

TABLE III.

Class of business	Old installation			New installation			Average increase in per cent. production	Total cost in per cent. of pay-roll
	Equipment	Watts per sq. ft.	Foot-candles	Equipment	Watts per sq. ft.	Foot-candles		
Iron pulleys finishing shop	Drop cords. 60 w. lamps Bare or tin shaded	0.27	0.2	200 w.-C. Reflectocap units	1.90	4.8	20	5.5
Soft metal bearing mach. shop	25-100 w.-B. deep bowl refl.	1.00	4.6	25-200 w.-C. deep bowl refl.	2.00	12.7	15	—
Heavy steel Mach. shop	13-100-w.-C. 23″ eye shield units	0.60	3.0	13-300 w.-C. in same units	1.70	11.7	10	1.2
Carburetor assembling shop	84-40 w.-B 2-100 w.-C. 14-40 w. drops	1.00	2.1	19-300 w.-C. 10-200 w.-C. eye shield units	1.90	12.5	12	0.9

DISCUSSIONS.

MR. MASSON: I want to say that this is a very valuable paper for my immediate needs. Just before leaving Los Angeles I had a talk with my superior and told him I hoped when I came back to have a lot of new and valuable ideas to make my services more valuable to the Company, and this paper furnishes a great incentive. I am glad to have Mr. Hogue's suggestions as a guide.

Thus far I have been doing missionary work in the field of illuminating engineering for the Southern California Edison Company. To date my department consists of one person, to wit, yours truly; and my main duty has always been to give illuminating advice to our lighting consumers. No thought has ever been given to ways of building up our lighting load, but I believe it is a vital part of my special job. I hope that after I have outlined this paper to my superiors, they will see it that way, too.

In the 200 cities and towns served by my company, there should be plenty of opportunity to build up our lighting load, and having in mind the excellent results obtained by the Commonwealth Edison Company, I expect upon my return to make immediate and profitable use of this knowledge.

MR. JOHNSON (Chicago): This paper would pay for itself, for its presentation here for one point if for no other. It is full of good things, but there is one statement on Page 2, I wish to call particular attention to. It is "Very little Local Lighting is Used, and such Local Lighting in all excepting one case is a remnant of the Old Lighting, and was not recommended by the Central Station Engineers."

Drop cord lighting, in other words, is gone—gone as far as economical, efficient installation is concerned, gone to all those who know what good lighting is. Mention is made here of a suggestion that wall receptacles be provided, that extension cords be checked in and out of the tool room, like a special tool.

I know of one installation where that method is being used. This is a tool and die making shop, and about forty stamping presses. The men were accustomed to using drop cords for local lighting on their machines. A system of general illumination was installed, and the use of any localized light of any kind

was not allowed for a period of three months. At the end of that time we allowed the men to obtain from the tool room an extension cord with a plug, lamp and a reflector with a clamping device to fasten the equipment to the machine. A receptacle on conduit coming through the floor at each machine was provided.

The men take their tool checks and go to the tool room and get this equipment. There are times in tool and die making, etc., where they do need some local light, but it is only in a small percentage of the cases. These men who obtain this equipment use it for fifteen or twenty minutes or longer, as the case may demand, and when they are through, the funny part of it is, that they return that equipment to the tool room. They are converted to general illumination. They believe in it. Now it is a good thing, they would not go back to the old haphazard sort of lighting as shown in the dismal shop at the electrical show. They are converts to general illumination.

It took three months of almost mutiny to convert them, but the officials of that plant said, "If you want to quit because you are not satisfied with the light, go ahead and quit; we don't care, but we are giving this a trial, and at the end of three months if you come to us and say it is not good illumination, then we will have to change it."

At the end of three months they were converted, and they did not want to change. The intensity at that time was not anywhere near as high as is shown in the third column from the right hand side in Table No. 1. There is another good point of the paper, the high intensities which the Edison Company are recommending. I can say here, living in Chicago, that I know the Edison Company are doing a great work towards the advancement of good illumination in this city. I believe that this paper, carried by the fellows here to different parts of the country, is going to result in the raising of lighting conditions in other sections of the country.

Another point, Table No. 11, Page 9, last column, shows average burning hours. So often when we are out on the job trying to sell good lighting—by the way, I claim now we are not selling reflectors, we are selling good illumination; the reflectors are just a cause leading to an effect, which is good illumination.

We have been stating to Plant Managers, that they use artificial lighting on an average of three hours a day. This table shows that we are wrong. I don't know just what the average is, but it is approximately five hours. The Plant Manager usually says, why should I put in good illumination? I don't work in the night time; my men are not working at that time—we work during the day, we don't need that.

But here is a table which carries through the whole year showing an average of something like five average burning hours per day when artificial illumination is needed. This is another talking point, in order to convince Plant Managers that they should have good artificial light, in fact, artificial lighting under which their men can do just as good and as much work as during the day.

On Page 10 I notice the statement, "If the installation is made along the lines of our recommendations, we do not count the labor lost." That is one trouble as is explained here, "that the small contractor, uncertain of his costs at best, and willing to hold profits to a minimum to keep his men working, is very likely to underbid us."

In my estimation, the electrical contractor is the biggest field that the I. E. S. has to work on, in this general propaganda in the advancement of the art and science of illumination.

As we saw on the chart yesterday, in Mr. Eastman's talk, the contractor, is called into consultation by sixty-two per cent. of the Factory Managers who wish to change their lighting system.

Sixty-two per cent. is far above any other source of information. The electrical contractor does not, as a general rule, figure on good illumination. One reason is as stated here. Another reason is that most of them do not know. I am not saying that do not want to learn; I believe they do; in fact, my contact with them has shown that they are willing to learn and willing to put in good lighting if they can get the other lighting interests who are bidding against them to do the same thing.

So we will have to have co-operation among contractors and all contractors boosting good illumination. When that time comes we will not have any trouble with these fellows underbidding and so forth, causing a poor lighting system to go in in place of

a good one. Our reciprocal relations committee in doing this work, in getting all the contractors working together along lines of illumination certainly is going to help as much as anything else to push this cause forward.

In the last table No. III, there is another argument as to why an electrical contractor or any one else who is boosting good illumination and who is working in the interests of his client. The values in the last two columns certainly show that if he wishes to give his client the best, he can't advocate anything but good lighting, and if he bids on something or if he tries to install something that is not up to that standard, he is not serving his client to his best interest.

For instance, notice the increase of business in the soft metal bearing machine shop, old installation, 4.6 foot candles, new equipment 12.7 foot candles, average increased per cent. of production 15.

Now the question is, what does 15 per cent. increase in production mean in that man's plant? Probably several hundred thousand dollars. The question is, whether a very few thousand dollars would pay for that good lighting system. I know it will. Good lighting is an investment. It is not an expense.

Let me say that ordinarily a plant manager looks on lighting, as has been referred to here, as a janitor service. He looks at his electric light bill, and calls that amount his lighting expense. If he should add to his electric light bill, the cost of his accidents caused by poor light, the cost also of spoiled materials and all its attendant evils, he will find that his cost of lighting on a poor system is far above what it would be under a good system.

When he has installed this good system with its elimination of accidents, its reduced spoilage, and its increased production, amounting to something like fifteen per cent., it hardly seems to me that anyone could advocate anything but the very best in industrial lighting. (Applause.)

Mr. Harrington (New York): I would like to obtain from the authors a little more dtailed information regarding Table I. I notice in this table that units ranging from 200 to 500 watts in size are employed and that the hanging height from the floor varies from eight to fourteen feet. In our work we have been

somewhat hesitant in recommending, say a 400 or 500-watt lamp at a hanging height of 10 feet because of the likelihood of glare and unevenness of illumination. With this hanging height the units must be spaced fairly close together to produce even illumination and consequently the resulting illumination will be quite high. On the other hand, if the units are spaced at distances which will give watts per square foot of floor area corresponding to present practice, then there is a strong likelihood of obtaining sections of high illumination and sections of low illumination. I would like to have the authors inform me regarding the results which they obtained as to glare, uniformity of illumination, and the like.

MR. HOEVELER: Mr. President, when I came with the Industrial Commission of Wisconsin they told me that while employers were required to provide certain safeguards in factories the policy of the commission was not to send around policemen to see that safeguards were put on. That what they wanted was men who would prove to the satisfaction of the employer that safeguards are a good thing. We have inspectors who have demonstrated that great increases in production may be realized with machinery that has been adequately guarded. I refer particularly to the punch press. Increases in production of 100 and 200 per cent. have been secured where such presses were made absolutely foolproof. When we started the lighting work we felt it more important than ever to try to show the employer that while the law required better lighting, it nevertheless was a good thing for him as well as the employe. Therefore, we are very happy, indeed, when we can get data which is authoritative and which proves our point. There was some available a few years ago and we have a good deal more now. I hope there will be more.

PROFESSOR CALDWELL: The title of this paper is "Factory Lighting, a Central Station Problem", but most of us will agree that the general run of central stations do not adequately realize this as one of their problems. It is for us to bring it home to them. As has been pointed out, the contractor or supply dealer is the man who usually acts as the lighting engineer for the industries. Now it is obvious that it is of more lasting financial advantage to the central station than to the contractor to promote

good industrial lighting, also the central station is in a somewhat better position to act as a consultant for the industrial concern than is the contractor. The average man is more impressed by immediate outgo than by the future expense, and he will more readily accept the advice of the central station than that of the contractor, who will shortly be sending him a bill.

In this connection, I would like to call attention to the proposed work of our educational committee. The new administration feels that the time has come for this Society to take a more active part in the education of the country generally, with regard to the proper use of light. Quite an ambitious campaign is therefore being outlined for reaching the users of light, as well as all who are connected in any way with the installation or maintenance of lighting systems. This, of course, includes the central station. Our committee has a large proposition on its hands, and we can carry it out successfully only through the active cooperation of all the members of the Society.

Mr. A. L. Arenberg (Chicago): I recall that before the introduction of the Mazda C lamp the intensity tables which were published by the Illuminating Engineering Society indicated requirements of above three to five foot candles for a large majority of industrial operations. We used to publish with our reflector literature tables of intensities that we recommended for industrial plant work, and we always added at least two foot candles to all those recommendations that were published by the Society at the time. We did this for two special reasons. First, we felt that higher intensities were a decided commercial necessity. We knew that we could increase production and we could reduce spoilage. However, we never had had any definite tests to prove those conclusions. Second, we wanted to eliminate any possibility of failure of the installation due to the fact that there is usually neglect on the part of those who maintain the installations. If we need three foot candles and start out with five foot candles, even if there is some neglect we will have always more than the minimum requirements and consequently won't have an absolute failure of the installation. Recently the Commonwealth Edison Company has conducted a series of very exacting tests and it is definitely proven than production can be greatly increased by tripled intensity lighting, and I feel that

there should be no hesitation on our part now to go ahead and recommend far greater power consumption per square foot than we ever have before. The only way to get this across to the consumer is through consistency in the recommendations by the various lighting engineers that are called in on the job. For instance, in Chicago, if the Edison Company goes into an industrial plant and recommends an intensity of twelve foot-candles for a certain operation and then if other specialists are called in and asked to plan the installation and make recommendations, and they recommend about eight instead of twelve it doesn't look well for the Edison Company. It seems as if they were trying to boost the power load without any real basis for it, whereas we are all absolutely convinced that it is decidedly to the advantage of the customer to use twelve foot candles. We should, therefore, get together and consistently recommend a high intensity so that there will be no confusion when the customer gets three or four recommendations from different sources. The central station company, the reflector people, the fixture people, the contractor dealer, I think should get together and standardize definitely on intensities for certain classes of work. If that is done there will be far less difficulty in putting in the proper lighting requirements.

Statistics show that ninety per cent. of the industrial establishments employ less than 250 people. This is the class of business we are most interested in and which we furnish our illuminating service to. The larger establishments, as a rule, have their own illuminating engineers or employ someone to handle their entire engineering work.

The question was asked, how we eliminate glare. We do not use the R. L. M. Reflectors, for the reason that before these reflectors were standardized we had developed two distinct types of reflectors.

The minimum mounting height for 300-watt lamp equipment is ten or eleven feet. The minimum mounting height for 400 watt lamp equipment is, as a rule, 14 feet, except in special cases where they might be mounted lower.

We use eye diffusers on all of our factory lighting installations, up to 200-watt. In the case of larger lamps we use what is known as the 800 H. B. Reflector, which has an opal collar.

ILLUMINATION OF ARTISTIC INTERIORS WITHOUT THE USE OF PENDANT CEILING FIXTURES.*

BY AUGUSTUS D. CURTIS AND J. L. STAIR.

Possibly the most radical change in the methods employed for

60 a

ERRATUM.

Discussion appearing in Volume 15, No. 1 TRANSACTIONS, page
, beginning with the 23rd line should be headed, Mr. Hogue. It
suggested that this notice be posted on the corrected page.

light and finally, the modern electric lamp. Interesting stories have been written, tracing the history of the lighting fixture through its various periods of utility and design. Our attention is now centered largely on the best uses of light for our comfort, for our pleasure and our practical requirements. We have arrived at the place where we are ready for the refinement in lighting methods and in the ways of using light.

In buildings of a public character, we are to-day getting farther and farther away from the use of the so-called lighting fixture. It has been found in many recent installations, that ceiling fixtures are not always necessary; in fact, they sometimes detract from the harmony of the interior. There are many cases in which we need not follow precedent and confine ourselves to the old arrangement.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, October 20 to 23, 1919, Chicago, Ill.

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BY AUGUSTUS D. CURTIS AND J. L. STAIR.

Possibly the most radical change in the methods employed for the illumination of certain classes of interiors during the past few years has been in lighting without the use of hanging ceiling fixtures.

This, in many respects, is a new phase of lighting practice, and seems to mark an epoch in the art, inasmuch as its applications are becoming more and more numerous. It is true that even in the carbon filament days, attempts were made to light certain interiors by cornice lighting, but few if any successes were recorded due to the low intensity resulting, the lack of proper reflector equipment and the lack of knowledge of the principles involved.

Higher standards in lighting practice are to be reached. We are passing through one of the important stages in the evolution toward the ideal in the art of lighting. Many mile-stones have marked the upward tendencies in this important activity, including the torch, the grease lamp, the oil burner, the candle, the gas light and finally, the modern electric lamp. Interesting stories have been written, tracing the history of the lighting fixture through its various periods of utility and design. Our attention is now centered largely on the best uses of light for our comfort, for our pleasure and our practical requirements. We have arrived at the place where we are ready for the refinement in lighting methods and in the ways of using light.

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The extent to which this concealed lighting method has been employed in the past two or three years leads us to predict that much of the lighting of the future will be accomplished from sources entirely concealed and without resorting to the use of hanging ceiling fixtures. In the future, the adoption of this method will be still further stimulated by further improvements in light sources and the further development of special reflecting devices. This does not mean, however, that there are not many interiors in which fixtures are most appropriate and will continue to be used, as for instance, interiors of the commercial type and those wherein, for certain artistic reasons, the designer wishes to retain the suspended fixture.

The methods are many whereby the illumination of interiors without ceiling fixtures can be accomplished. Lighting units may be concealed in projecting coves or cornices; may be placed in wall boxes or in the caps of columns; hidden in the tops of floor pedestals; used in art lamps; in display cases; in urns, etc. The individual characteristics of the interior usually suggest the most suitable method.

One finds, in applying this method, that it takes many unexpected turns; it has many interesting and pleasing situations, and is the means, whereby many of the beautiful things in lighting may be realized.

Time and space permits of the description of only a few of the many applications of lighting without ceiling fixtures. Many methods are used which are not represented in this discussion.

THE AMERICAN THEATRE, CHICAGO.

Soon after the indirect lighting system, as we see it to-day, became a commercial reality, one of the earliest attempts at lighting without fixtures was made in the American Theatre of Chicago. Although the installation does not represent the greatest possibilities in the illumination of this interior, it does indicate the general trend in indirect lighting at that time.

The balcony view of this theatre Fig. 1 shows that considerable ingenuity was used in concealing the lamp in the reflector equipment along the front of the balcony rail, and in the stair wells leading into the balcony from the second floor lobby. To one

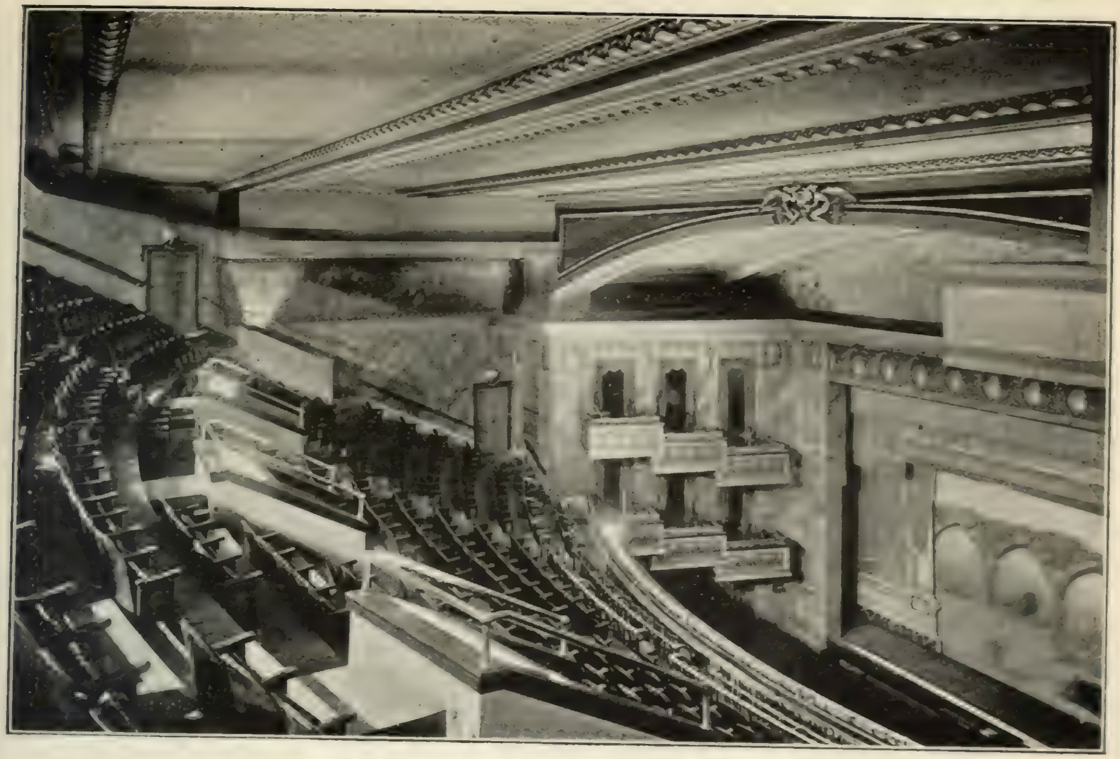


Fig. 1.—Auditorium, Balcony View American Theatre, Chicago.

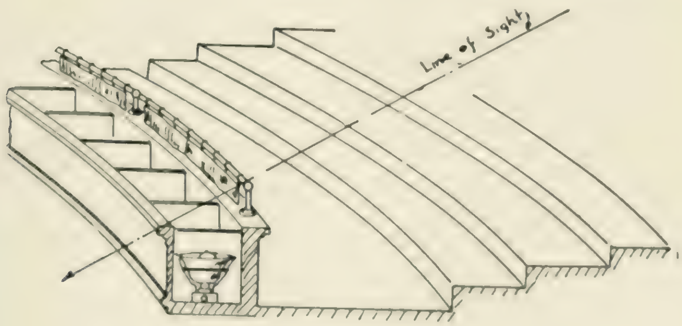
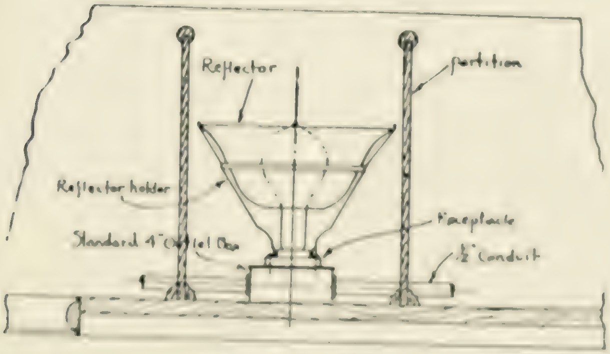


Diagram showing arrangement of reflector equipment on front of balcony



Section of Compartment

Fig. 2.—Lighting arrangement for American Theatre, Chicago

Fig. 3.—Dining Room, Bank of Commerce, New York.

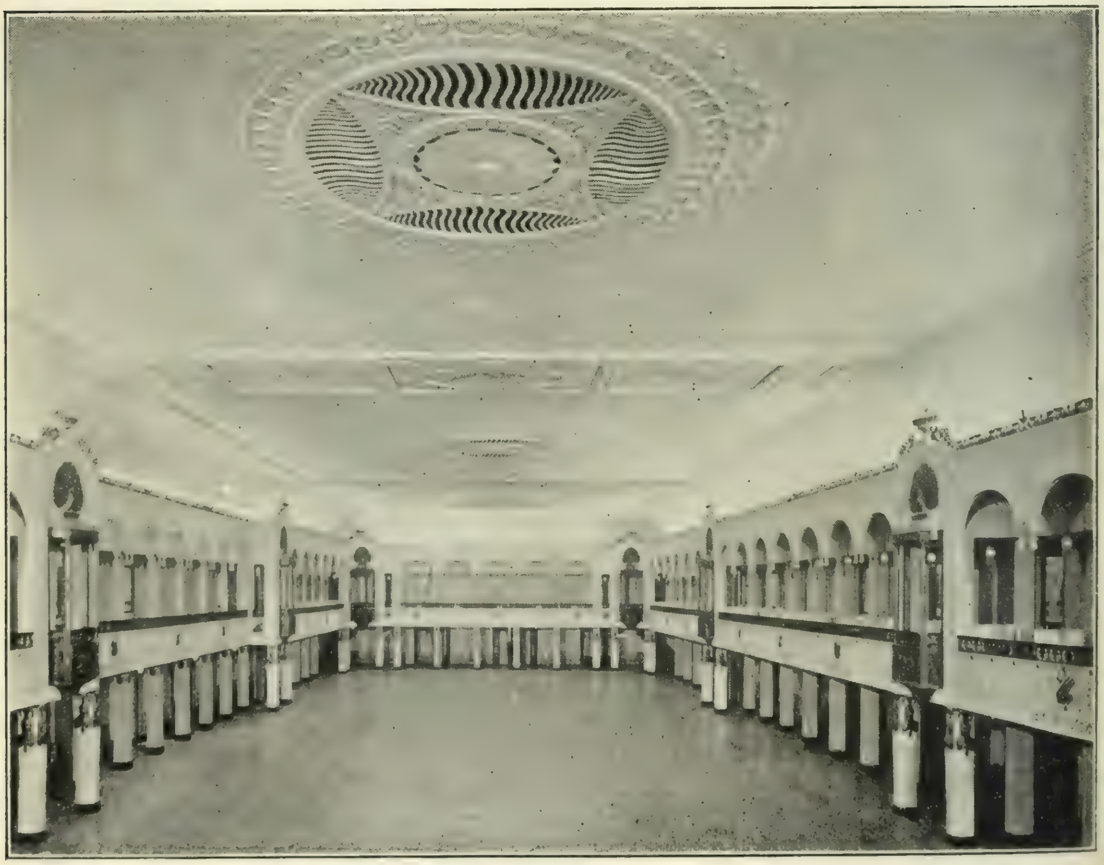


Fig. 8.—Ballroom, Hotel Commodore, New York.

seated in the balcony, no lamps are visible, and only the extreme ends of the lighting compartment along the front of the balcony are seen. The construction of the compartment is detailed in Fig. 2.

Viewing the balcony from near the stage it is not at once apparent that the projecting compartment has been added, so well does it fit into the architectural treatment.

NATIONAL BANK OF COMMERCE—DINING ROOM, NEW YORK CITY.

It is often impractical to construct a continuous cove, pocket or compartment about the room for the concealment of the lighting units, but yet it is desirable to illuminate the interior from hidden reflectors. A method is advantageously employed wherein especially shaped reflectors in bracket units are placed directly against the wall or on columns. The light is projected to the ceiling, away from the supporting surface. In Fig. 3 is shown the practical application of this method in the dining room of the National Bank of Commerce, New York City.

This method of bracket lighting is especially suitable for low ceilinged rooms and for theatre auditoriums where an unobstructed view is desired in all directions. In theatres the usual method is to provide wall boxes containing three or four units instead of single units as shown by the illustration. The units are wired on separate circuits, thus providing several intensities of illumination, adding greatly to the flexibility of the installation.

NATIONAL BANK OF COMMERCE, NEW YORK CITY, DINING ROOM.

Size of room	30 ft. x 80 ft.
Floor area	2,400 sq. ft.
Ceiling height	11 ft.
Number of fixtures	48 wall urns
Lamps per fixture	1-75-watt Mazda C. (gas filled tungsten)
Type of reflector	Mirror glass[1]
Wattage consumed	1.5 watts per sq. ft.
Fixtures suspended	48 in. from the ceiling
Fixtures spaced on pillars	8 ft. apart

[1] X-Ray-R-65.

LOBBY, HOTEL COMMODORE, NEW YORK CITY.

One of the most interesting instances of lighting without ceiling fixtures is to be found in the lobby of the new Commodore Hotel, in New York City.

The name that the Commodore Hotel bears is a delicate compliment paid to the late Commodore Vanderbilt, founder of the New York Central Railroad, at the very doors of the main terminal of which the hotel now stands.

The lobby is the principal show feature of the hotel and is a marvel of beauty. It is not only the largest hotel lobby in the world, but is also arranged in a manner entirely unlike that in any other hotel.

It was designed by the architects to represent a great Italian garden or courtyard. The walls are rough plaster above the wainscoting of soft Italian stone. The panelling is set with blue tiling and the ceiling is of white glass, supported on decorative beams.

Those who have not had an opportunity to view this lobby with their own eyes may gather from the illustration in Fig. 4 some idea of the picture it presents.

In the Hotel Commodore is to be found all that is most advanced in the mechanical and decorative arts. The lighting problem of the lobby, therefore, called for careful study and necessitated a *different* kind of treatment. The whole lighting scheme was worked out to fit the architectural requirements of the interior.

Since the lobby is to all intents and purposes an Italian garden, there is no legitimate place for lighting fixtures of the ordinary hanging type. They were entirely omitted and the illumination effect obtained by means which will now be described.

One might expect, in a garden, to find the principal illumination coming from the sky above, hence to carry out this idea a glass ceiling was built to be used in imitating a skylight effect for the artificial illumination. No daylight, however, enters the room through this skylight, since it is entirely covered by other portions of the building, and is made up of dense white glass.

The first impression, upon entering the room, is that it is lighted by units placed above the glass ceiling. Even experienced lighting men have gained this impression upon first coming into

the interior. The light emanates from ten floor urns and twenty-two gargoyle fixtures; is directed to the glass ceiling, and reflected from it. To assist in creating a skylight impression, the framing is carried out in very dark tones, so as to reflect only a small portion of the light and to give the effect that the glass panels only are luminous.

The urns and pedestals for the lighting are ingeniously placed so as to fit in harmoniously with the decorations of this elegant interior.

The following data is given as a record of the mechanical equipment used to produce the lighting results.

HOTEL COMMODORE, LOBBY, NEW YORK CITY.

Size of room........................48 ft. x 140 ft.
Ceiling height........................26 ft. 6 in.
Square feet area......................6,720
Total watts...........................11,700 watts
Watts per square foot consumed.....1.74
Equipment employed..................6 center urns each containing 4 lights with 300-watt lamps and EC-345 reflectors; 22 No. E-65 gargoyle Brackets, each with 150-watt lamps; 4 end urns, each with 1-300-watt lamp and EC-345 reflector.[1]

Over each of the four lighting units contained in the center pedestals in the lobby, is an especially designed hinged cover with louvres, having two sets of fins set at 90° to each other, as represented in Fig. 5. These louvres serve to cut off the light sharply at the balcony line and also make it impossible to see exposed lamp filaments from the balcony.

Fig. 6 shows, in a diagrammatic way, a section and plan view of the gargoyle bracket fixture. A special type of non-symmetrical silvered glass reflector is imbedded in the plaster work, and redirects the light from a 150 watt lamp out over the ceiling area. Mounted directly above the mouth of the reflector is a hinged door with louvres, the function of which is to prevent a back splash of light on the columns and to conceal from view the lamp and reflector equipment from the balcony across the way.

[1] Mirror glass reflectors, the designations refer to X-Ray reflectors, the lamps are of the Mazda C type, (gas filled tungsten).

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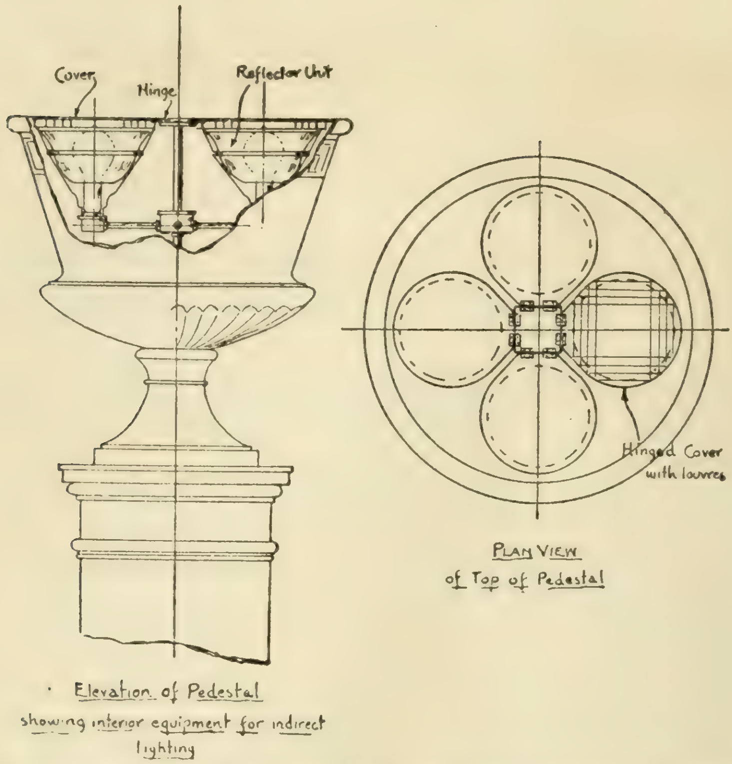


Fig. 5.—Details of lighting standard for Lobby, Hotel Commodore, New York.

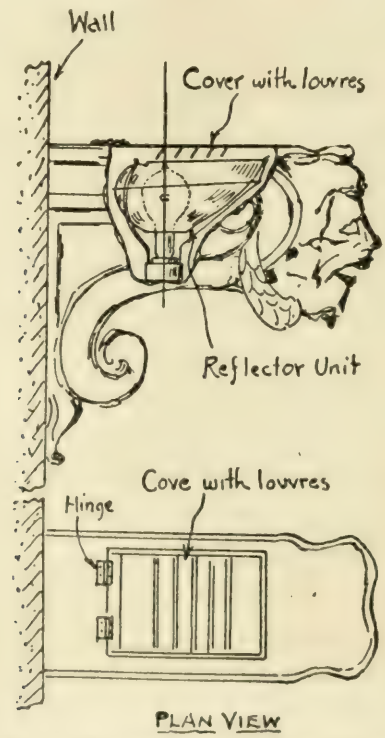


Fig. 6.—Detail of Gargoyle fixture, Lobby, Hotel Commodore, New York.

Fig. 4.—Lobby, Hotel Commodore, New York.

66c

Fig. 7.—Lobby, Hotel Commodore, New York. Looking west from balcony.

BALLROOM, HOTEL COMMODORE.

The Hotel Commodore houses the largest hotel ballroom known. A huge interior 78 ft. in width and 180 ft. long, encircled by a gallery divided into fifty-six boxes with the customary promenade behind them. The decorative scheme and furnishings of the room are Italian, carried out in delicate shades of orchid, purple, white and gold, with a base of emerald green. (See Fig. 8.)

To flood the interior with diffused illumination and to retain the spacious appearance, the cove or cornice method was adopted, with reflector units running along two sides of the room. No reflectors are employed within 6 ft. from the corners of the room, otherwise they are symmetrically spaced about 15 in. apart. All units are wired on two circuits, with every alternate reflector on one circuit. For one set or circuit, an amber film is placed over the mouth of the reflector, allowing for a variation or tinting of the light. The table below gives detailed information on the equipment used to produce the results.

HOTEL COMMODORE, BALLROOM.

Size of ballroom proper....	52 ft. x 162 ft.
Ceiling height..............	28 ft.
Square feet area...........	8,424
Total watts consumed.......	23,200
Watts per square foot......	2.75
Equipment	232 No. 610 reflectors in cove with 100-watt Mazda C lamps.

Cove lighting, although one of the oldest forms of concealed lighting, requires careful planning to insure a uniformly lighted ceiling and an absence of light and dark patches that so often unmistakably indicate the position of the individual reflector units in the cove. Great possibilities have been opened up for the illumination of interiors by this method, since the introduction of the powerful Mazda "C" lamp and the design of efficient reflectors for this particular application.

To insure pleasing results in any given case, the proper size and style of reflectors should be carefully determined. The coves should be amply large to contain the suitable equipment and should be placed not too close to the ceiling, if ceiling brightness

is to be obtained. A means should be provided whereby the reflector equipment can be easily reached for cleaning and renewing of lamps.

COMMONS CHAMBER, HOUSE OF PARLIAMENT, OTTAWA.

On February 3, 1916, the Parliament buildings at Ottawa, Canada, were burned with a loss of five lives and a property loss of about $6,000,000. The work of reconstruction was begun without delay. The Dominion Government is replacing the old buildings with a new one which it is estimated will cost at least $5,000,000.

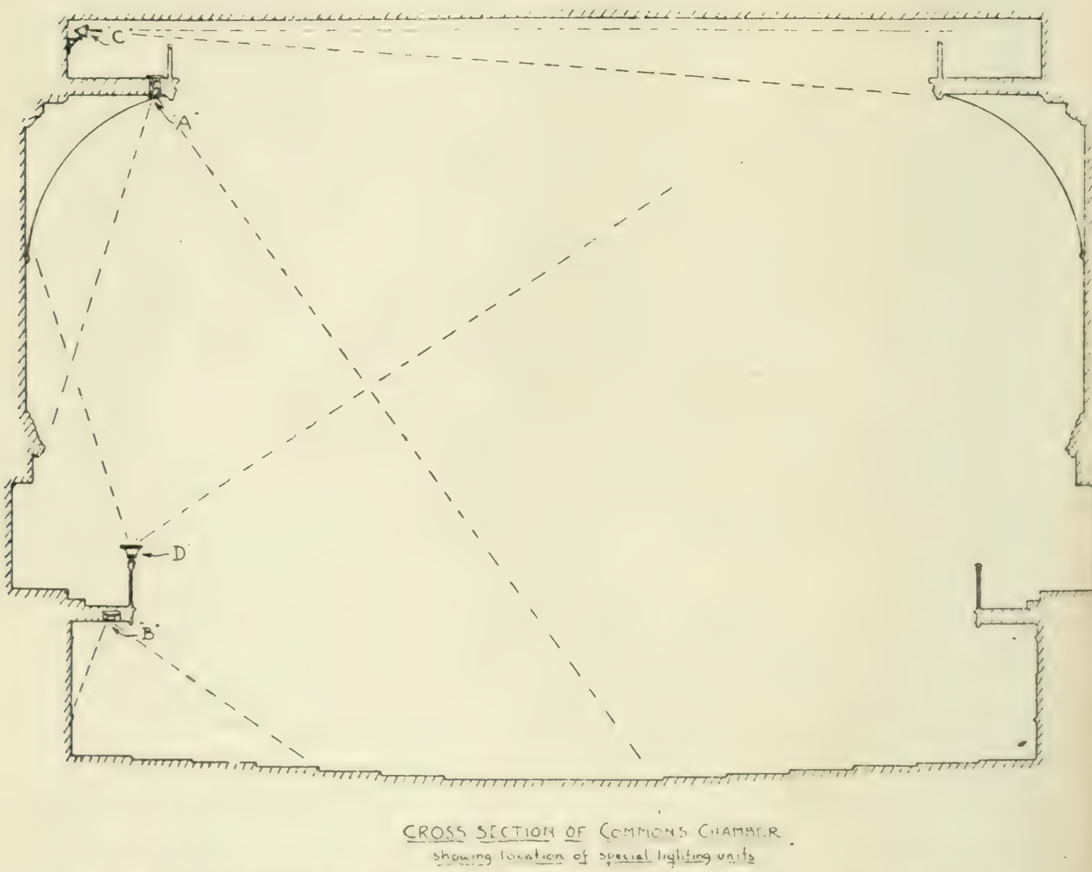


Fig. 9.—Cross Section of Commons Chamber, House of Parliament, Ottawa, Canada.

The lighting of the Commons Chamber only will be discussed here. The methods employed for the illumination of this interior, it will be agreed, are very unusual and mark this as one of the most novel installations that has recently been made, yet entirely in keeping with the dignity of the Commons Chamber.

The structural features of the room made it necessary to resort to special methods—ceiling fixtures could not well be employed.

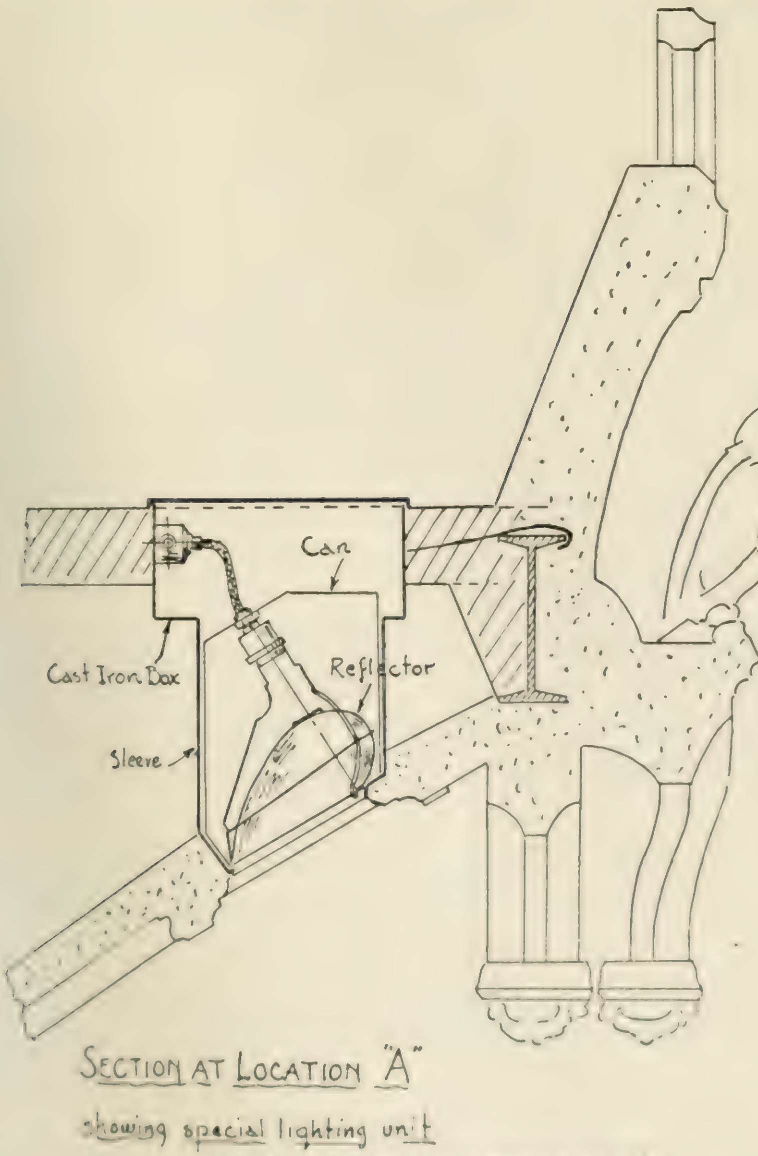


Fig. 10.—Commons Chamber, Ottawa, Canada.

In the Commons Chamber, which measures 62 by 97 ft. exclusive of the galleries, with a ceiling height of 50 ft., the general illumination is obtained from a total of sixty-four special reflector units, each with a 150-watt Mazda "C" lamp, mounted in the upper gallery as shown in Fig. 10. These units are spaced in groups, the actual location of which has been governed by the ornamenta-

tion of the upper gallery. Thirty units are provided over each side of the room and four at the front end over the reporter's gallery.

It might be mentioned that in this Chamber the members are seated on either side, facing the center of the room. The type of reflector equipment at this point is, therefore, of great importance. As the main illumination of the room is to be by direct lighting, it was necessary to so place the units that they would offer no great objectionable glare to the people below. The reflector installed at this location (see Fig. 9) is one designed to cut off the light sharply on one side, hence with the units properly installed it is impossible for a representative seated at the opposite side of the Chamber to see the lamp when looking upward.

A cylindrical opening is required at the location of each of the units so that the reflector mounted at the proper angle in the cylindrical fixtures may be dropped down in the place from above. This arrangement provides for cleaning reflectors without removing them from the cylinder.

As the galleries project somewhat it was necessary to install a total of ten units under the galleries, five on each side. A reflector accommodating two 40-watt Mazda "B" lamps at this point was installed and the entire equipment is countersunk in the ceiling.

The lighting units mentioned above provide for purely useful illumination of the room and are supplemented by two additional systems.

One of these consists of ten ornamental standards in the side galleries, five on each side, each equipped with a special reflector attachment of 450 watts capacity. These pedestals are designed to harmonize with the general treatment of the interior and are surmounted by a bowl or urn about 24 in. in diameter which accommodates the reflector units.

The use of this additional equipment gives a system of indirect illumination which does much to create an atmosphere and relieve the purely direct lighting. It assists in giving height to the interior and bringing out the architectural treatment of the ceiling, and serves to eliminate any sharp shadows that might otherwise occur.

Another system of lighting is provided to bring out the upper gallery crown ornament. The indirect illumination provided, is of a comparatively low intensity so that the general effect on the main ceiling will be darker than on the lower sections of the room. It was particularly desirable in this case to bring out the upper balcony rail or cresting by concentrating light upon it. This is done by means of special projector units concealed at point "C" and so adjusted that the light is directed on the rail on the opposite side of the room. These units are designed in such a way as to give a band of light upon the rail section, causing this portion to be more highly illuminated than the section directly below.

COMMONS CHAMBER, HOUSE OF PARLIAMENT, OTTAWA.

Size of room..............................62 ft. x 97 ft.
Floor area...............................6,014 sq. ft.
Height of ceiling.........................50 ft.

EQUIPMENT EMPLOYED.

"A"—64-special unit, reflector X-Ray No. E-65 lamp, 150-watt Mazda "C"

"B"—10-special unit, reflector X-Ray No. 750, lamps 2-40-watt Mazda "B" for each reflector

"C"—30-projector Type Unit, fitted with special covers, 250-watt Mazda "C" Flood Lighting Lamps in each

"D"—10-urn unit, mounted in rail Reflector X-Ray No. E-65 Lamps, 100-watt Mazda "C", 3 lamps for each urn

PANTHEON THEATRE, CHICAGO.

The Pantheon is one of the modern examples of the progress of the motion picture. It is a Pompeian temple built for the cinema, at a cost of nine-tenths of a million dollars. Among the hundreds of touches of modern skill in the arrangement of detail, comes the changeable lighting system.

In addition to the ordinary requirements of the theatre auditorium, illumination effects are coming to be more essential in the production of photoplays, in suiting the lighting to the action and atmosphere of the play. The theatre of the future will no doubt utilize harmonious lighting effects in the presentations. The means for doing this are now within the reach of exhibitors.

Color effects are especially effective with an indirect system of lighting, since an almost perfect mixing of the various colors can

be obtained and the illumination evenly diffused throughout the room. In the auditorium of the Pantheon Theatre (see Fig. 13) all of the lighting equipment is contained in the cornice near the ceiling. Four series of units are employed, one for white lighting and one for each of the primary colors, red, green and blue. Standard Mazda "C" 200-watt lamps are used in non-symmetrical silvered one-piece corrugated reflectors. Color screens of glass are mounted above the openings of the lighting units.

A system of dimmers in circuit with the lighting units provides an easy means by which the auditorium may be lighted so gradually that one is scarcely aware of the increasing intensity. Then the colors of red, green or blue, or various combinations of these colors, can be passed through to clear white lighting, gradually receding to almost actual darkness, without a noticeable flicker.

Many of the most modern theatres have been planned with the idea of making color effects a part of the lighting scheme, using methods by which the ceiling fixtures are replaced by other containers for the lighting units.

The details of the Pantheon installation, showing the panel board and cove lighting equipment, are to be found in the illustrations. In this instance, the color features were not confined to the auditorium alone, but an elaborate system has been installed on the stage, in the foyer and for the pylons on the exterior of the building.

AUDITORIUM, PANTHEON THEATRE.

Size of room	85 ft. x 140 ft.
Floor area	11,900 sq. ft.
Height of ceiling	45 ft.
No. of reflector units in coves	256
Kind of reflector used	X-Ray No. 610
One lamp in each unit	200-watt Mazda C
Wattage consumed (each color)	1.08 watts per sq. ft.

If pleasing results are to be obtained in the application of this method of lighting without ceiling fixtures, careful planning and co-operation on the part of the lighting man, the architect and the contractor are necessary. There are numerous instances in which the architectural design and detail has been modified to conform to the lighting plan, but without compromising in any way the decorative and architectural features of the interior. In some cases it may be necessary to design special reflectors in order to properly direct and control the light.

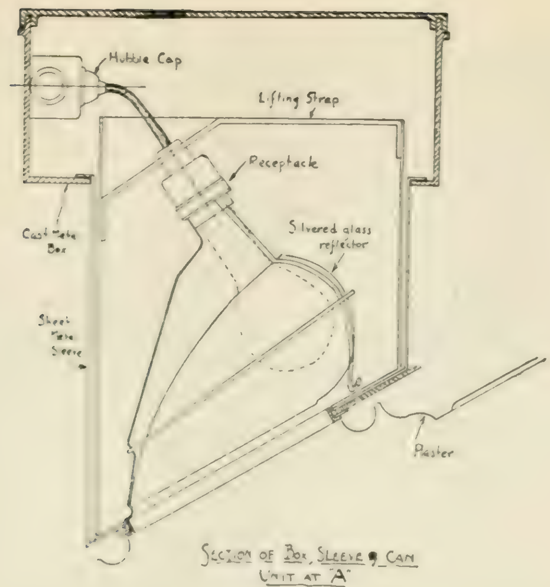


Fig. 11.—Detail of special fixture for Lighting in Commons Chamber, Parliament Building, Ottawa, Canada.

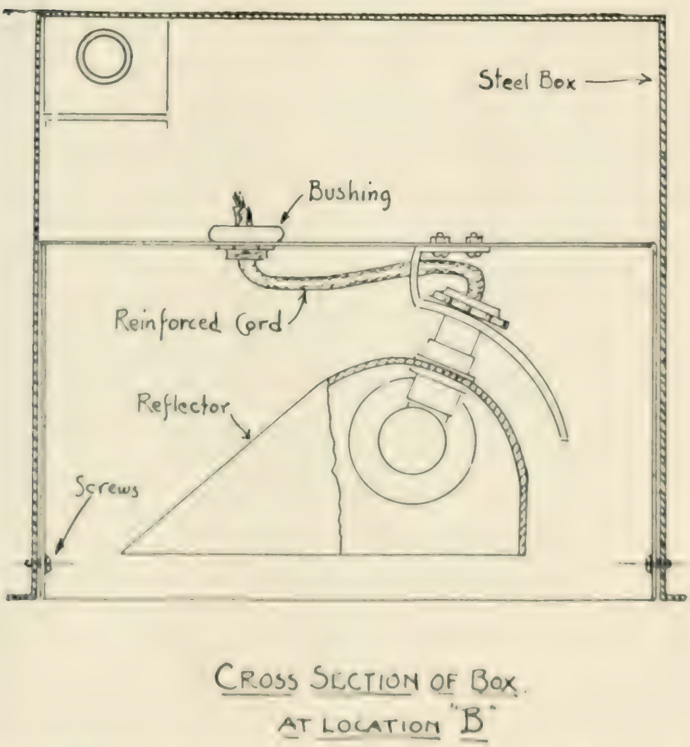


Fig. 12.—Lighting Unit for under Balcony, Commons Chamber, Ottawa, Canada

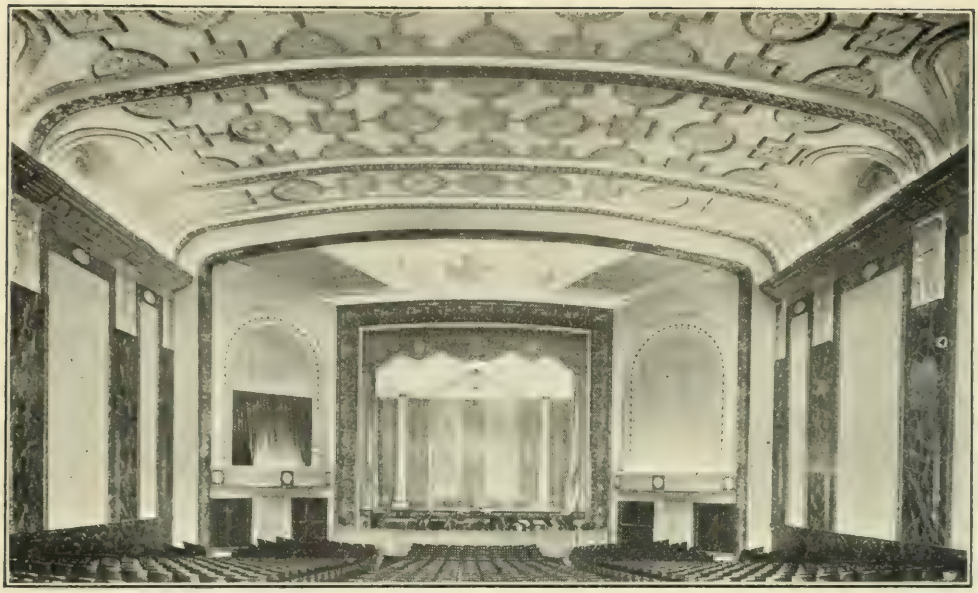


Fig. 13.—Auditorium, Pantheon Theatre, Chicago.

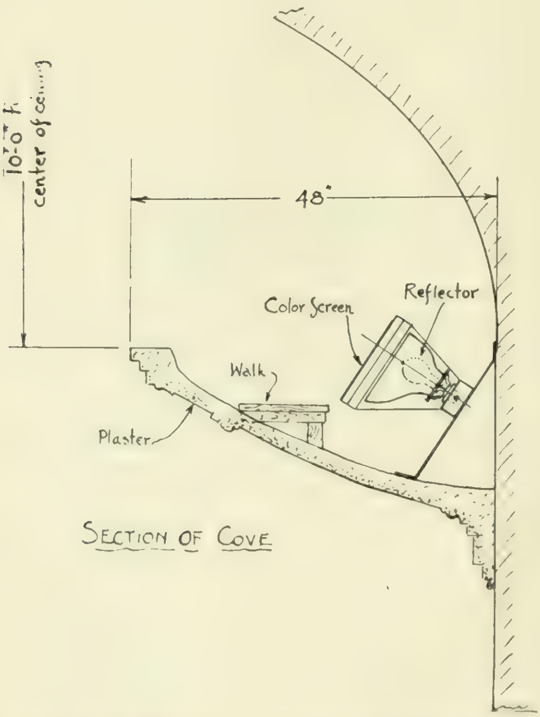


Fig 14.—Cove lighting detail, Auditorium of Pantheon Theatre, Chicago.

Great variety in lighting effects are possible because of the flexibility that characterizes this method. Its applications are almost unlimited in extent. It can be and is used in stores, display rooms, and offices; in the home and in many other places where, on first thought, ceiling fixtures might be considered the only practical method.

DISCUSSIONS.

Mr. A. L. Powell: The question of the satisfactory illumination of the artistic interior is one of the most fascinating phases of our business. The indirect unit which is not suspended from the ceiling offers one of the best and most practical means of obtaining the desired results. It is not always necessary to employ special or expensive equipment. Some of the standard direct lighting devices inverted and slightly modified often prove very useful. In other cases, simple home-made appliances fit the conditions far better than anything regularly standard in the way of lighting fixtures.

I have in mind a sun-porch where very simple home-made fixtures form a most pleasant means of lighting. We naturally associate the solarium or sun-parlor with the conservatory and in this case, two direct lighting metal angle type reflectors were inverted and attached to the side wall. A green wire flower basket filled with artificial moss and some fabric flowers inserted around the edge of this basket concealed the mechanism of the lighting unit from view. The light from 40-watt MAZDA lamps shining thru the flowers rendered them luminous; the reflection from the ceiling lighting the room by the indirect method

I recall another example in a beautifully artistic Colonial church. This originally had a system of lighting employing bracket units, which did not diffuse the light, on posts above and below the balcony. This glaring light was annoying and detracted materially from the beauty of the church. The architect required that the auditorium should be illuminated without the use of lighting fixtures. A number of schemes were experimented with but the one finally installed consisted of six deep boxes built along the front edge of the balcony. In the bottom of these boxes a standard bowl shaped steel reflector pointed upward was installed. The depth was sufficiently great to en-

tirely hide the light source from persons standing in their normal positions in the balcony and also to serve a very useful function in eliminating the spilled light.

If a standard bowl shaped reflector is pointed at the ceiling, there are likely to be circles of rather bright light overlapping on the side walls. This fact is, of course, very inartistic and must be avoided. In the particular case in hand, an experimental box was constructed, hinged on four sides and moving these backward and forward, it was possible to obtain the exact contour of a wooden box which would cut off the light sharply at the junction of the ceiling and side walls at the same time giving very even illumination on the ceiling itself. An adjustable experimental shield or a box of this nature proves very useful in much of the preliminary work of the class under consideration.

Decorative temporary lighting offers another field for the use of the lighting fixture not suspended from the ceiling. The illumination at Thomas Edison's seventieth birthday party has already been described in the technical press. This was held in a building of mill type construction where it was impractical to install any sort of decorative lighting from ceiling fixtures. Around each column, a simple wooden frame was constructed and at the four corners angle type steel reflectors were inserted. It was not essential to obtain a high efficiency of utilization and an inexpensive type of equipment was suitable. The frame work carrying these was then covered with a piece of bunting and colored lamps used in rows the length of the building, red, orange, yellow, green, blue, and violet, respectively, from north to south. The entire ceiling assumed the appearance of a gigantic spectrum and the shading of color from one row of units to another proved extremely effective and produced an effect which was remarkable in its beauty.

Ordinary devices of this character prove extremely useful to the lighting man when he has some special effect he is desirous of creating.

MR. WILCOX: I believe this idea of illumination, or at least the elimination of the fixture, is epoch making. Ever since man has used artificial light, he has been a slave, more or less, to cer-

tain conditions or ideas which have conventionalized his methods of use of light.

The flame lamp always required, of course, the vertical position, and with the adoption of the non-flame burner, we were freed from that limitation. Nevertheless, we continued as a matter of habit, the use of the pendant fixture supporting, even the electric light, and as you will remember the earliest electric light fixtures, we had the electric light turned up in the same manner as the flame burner.

Now we pass on to the condition where, with improved methods and appliances and engineering equipment, we are able to dispense with any fitting or any fixture or structure directly in the line of vision.

It has been well said that one feature of efficient engineering is an unconscious condition. A man who is healthy is absolutely unconscious of his physical self. It is only when he is suffering from illness that he considers himself from a physical standpoint. This form of lighting described so beautifully in this paper subscribes very fully, I think, to that idea of the unconscious effect.

We light our interiors just as they would be with daylight, in fact we can surpass the effect of daylight admitted through windows. This form of lighting has always been interesting, that is, lighting from concealed sources. It has appealed to me from the very beginning. Some of the most beautiful lighting effects that have ever been produced in lighting have been by this method. It may be well said to contain the elements of wizardry in lighting.

The English illuminating Society some months ago debated the effect from an illuminating engineering standpoint, of the introduction of the gas filled lamp, and in my paper on this topic. I pointed out as a possible development, this passing from the condition of the lighting fixture. With your permission, I will just quote this one paragraph:

"In gas lighting, a chandelier or fixture hanging in the center of the room, was required to support the flame burner. Out of this practice grew the fashion of the lighting fixture suspended from the ceiling. Electric lighting continued the fashion, and the trail of the fixture is still over the lighting industry today. Now the gas filled lamp, causing the obsolescence of direct light-

ing, modifies the fixture into a bowl, and thus frees lighting from conventional equipment and methods. The indications are that this evolution will continue and will tend to eliminate the fixtures as such, and clear the ceiling and interior of all exposed lighting equipment."

MR. CURTIS: (in reply) Nothing to add that I know of except that the subject is so very large and the field so prolific that with the suggestions and assistance of the Illuminating Engineering Society we are bound to have generally improved conditions. I am sure, as Mr. Wilcox has said, we feel and I guess we all appreciate that this possibly is an epoch making time in illumination. Possibly ten or fifteen years from now or further than that when we are sitting by the fireside smoking our corn cob pipe and reminiscing over the days gone by we will recall to our children the historical way of the old method of the brilliant exposed modern suns that caused their dads to suffer physical and mental anguish, and that they are very fortunate to be able at that time to live in an epoch where eye comfort is to be had. The point I made regarding the architects I wish you to remember because they are somewhat slow to come to any changes from the old method of construction, decoration, ventilation, illumination, heating. Now there is a great building spurt taking place. Practically everything is being changed in the world. The Illuminating Engineering Society should lose no opportunity to call the attention of the busy man to the opportunity for changes in the lighting effects.

A SURVEY OF INDUSTRIAL LIGHTING IN FIFTEEN STATES.

BY R. O. EASTMAN.

There is a very hopeful inspiration in the general impression that I have gathered as an observer of your proceedings to the effect that you gentlemen are apparently disposed to accept a contribution that is brought to you on the basis of what it is worth and what it is good for rather than who it comes from. As a rank outsider, and a sort of a layman, I appreciate that. A few months ago it was my lot to be called into the study of a business which was literally overrun with engineers. There were all sorts of engineers. There were mechanical engineers and electrical engineers, construction engineers and highway engineers, and low way engineers, civil engineers and uncivil engineers, engineers in charge of this and engineers in charge of that, engineers for everything. It was up to me to get very well acquainted with the organization and its personnel. In the course of doing so I ran onto a very busy young man who seemed to be here, there and everywhere. I finally asked him what his particular activity was. He said, "Well, I guess you'll have to put me down as engineer in charge of waste baskets, spittoons and inkwells. So I come to you today in a certain sense in an engineering capacity, representing the engineering activities or the engineering phase, rather, of selling activities in business. I am sure you will appreciate that there is a real field of very great opportunity for such activities. My activity is very largely that of the study of business and its market.

As I see the study of a market, it requires the same general type of analysis that applies to any other engineering activity. You must secure from the whole composite mass that confronts you typical examples and careful distribution and then arrive at the net result. What I am bringing you today is the result of a commercial investigation in the industrial lighting field, or rather only a few high spots from that general investigation. I refer to it as a commercial investigation because it is designed primarily to afford those for whom it was conducted, in this instance the National Lamp Works, the basis for the extension of their

commercial sales and advertising activities, but in all such investigations we arrive at an important engineering by-product that is just as truly of value as if it were conducted solely for the advancement of the engineering activities. There are some few things that we think are perhaps established or at least clearly indicated for the first time as a result of this survey, and that is what we want to bring to you.

The planning of such a survey calls, first of all, for a very thorough distribution of the samples. In this particular instance the thing we were after, bear in mind, was the general condition of industrial lighting, factory lighting throughout the country. Now to get that means that we must get types of all kinds of institutions throughout different parts of the country geographically, throughout different stratas of population, large, medium sized or small towns, old and young institutions, large, small and medium in size. It is in the distribution of these samples that we secured our greatest assurance of accuracy of results rather than a great volume of evidence as is true in all research work. The investigation was conducted by laymen, because, as I said at the outset, the first object was to secure commercial data. However, the fact that these men were not engineers, the fact that they had no great technical training I think was an asset rather than a handicap because such a man must necessarily go out with no prejudice and with a true student's mind. The men were of course trained in those things that it was necessary for them to know in order to report intelligently. That was all we required.

In the conduct of an investigation of this kind there are three distinct steps, as is true of all research work, which parallel very closely the way in which the colored preacher said he constructed his sermon. When asked how he made up his sermons he replied, "First I tells them what I'se going to tell them, then I tells them, and then I tells them what I'se told them." That, literally, is what you have got to do. First you determine what you are going to find out, then you find out, and then you tell what you have found out. In other words you determine it objectively, conduct the survey and finally submit the whole to an analysis which gives you the net or average for the entire group.

In our organized questionnaire we had a number of different headings, chiefly these: First, the equipment of the institution, second, as accurate as possible a history of the last lighting change; third, a story of the control of the lighting proposition within the institution, that is to say, where the lighting changes initiate, who supervises installation, to what extent are matters delegated to the chief electrician, what is the function of the engineer, who has to be sold. Now, you people are just as much interested in who has to be sold as if you were salesmen, because the whole activity of this organization is selling activity. It means just the same thing if you are selling an idea that it does if you are selling merchandise. Therefore, as I say, as I bring to you some of the results that we found as to who has to be sold, who are the factors of importance throughout this field that has to be cultivated, I think it is just as much to the interest of the I. E. S. as to the National Lamp Works, or any other commercial organization.

Then the results so secured are submitted not only to a general analysis to secure general averages, but, also to what I consider very important, vital cross analysis. First, by volume, for you find entirely different conditions prevailing in different geographical sections of the country; second, by population strata for you will find that certain types of towns have been more carefully cultivated than others, certain types or sizes of towns more or less neglected; third, by size of institution, for there is a remarkable difference between the general lighting activity and sense of lighting propaganda and development in the large as against the small institution; fourth, by age, for there is a great deal of difference between the mental attitude of the old and established concern and that of the young, growing concern. Sometimes, on some features, the old concern is more ready to adopt the things that you have to present to them because they realize their greater need of it. In other respects the young concern shows the result of young life and virile blood. Fifth, according to lighting requirements which is entirely a classification of its own. In the training of our men let me say they were skilled to understand and apply the I. E. S. code as to the various classifications of lighting requirements, and the reports are based accordingly on that classification.

Let us go into some of the general results of this investigation, which are presented in the form of charts. The shaded area in

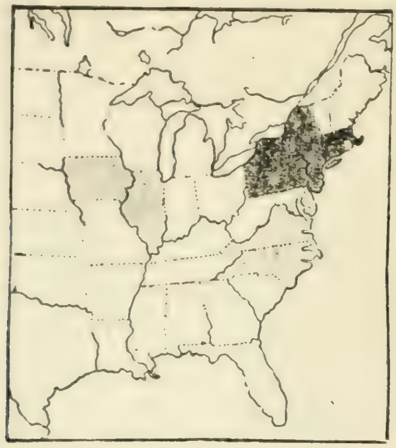


Fig. 1.

Distribution of Interviews by Kind of Business

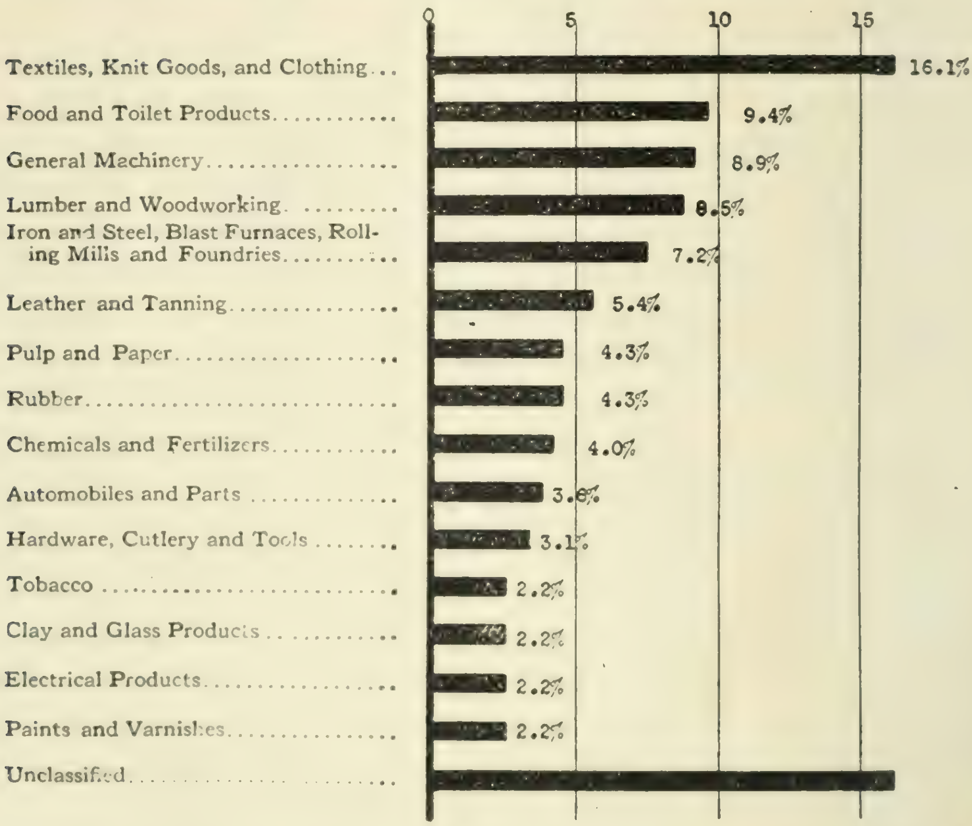


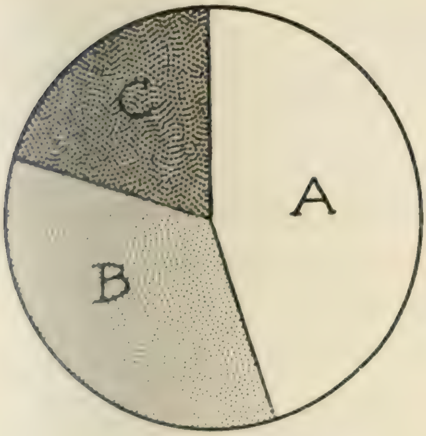
Fig. 2.

Fig. 1 show the general distribution of these interviews or of the entire investigation. It is confined very largely to industrial

areas which from the standpoint of population are the center of industrial activity, and represents industrially the greater part of the country, even though it is a small part of the country geographically.

In the distribution of interviews, extreme care was taken to cover all these various classifications, but particularly to take in all fundamental conditions of industrial activities. It is not necessary to dwell upon this in detail except to show the various divisions covered together with a large miscellaneous, unclassified division down at the bottom.

Fig. 2 shows the distribution of the plants investigated among the various industries.



Intelligence of Men Interviewed Regarding Efficient Industrial Lighting

A—Intelligently informed 44.5%
B—Vaguely informed 36.4%
C—Not informed............. 20.1%

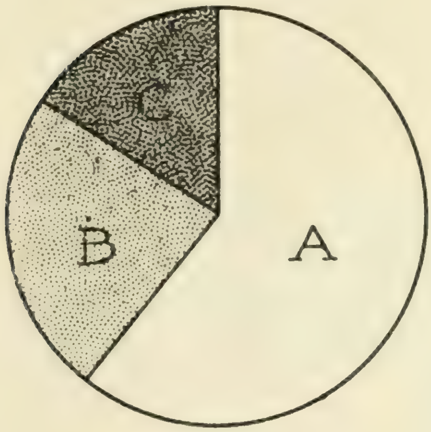
Fig. 3.

Fig. 3 shows one of the important net results of the survey. The extent of intelligence encountered regarding efficient industrial lighting, the degree to which these people knew what efficient lighting was is shown. We find 44 per cent. rated by investigators as intelligently informed, 36 per cent. as vaguely informed, and 20 per cent. as uninformed. Regardless of whether the standards applied by the investigators correspond with those which you or I might establish, these variations must be significant and this I think is of extreme importance to this Society.

Four primary divisions are indicated in Fig. 1, representing the western states, the central states, the New England states—with which New York was included—and the southern states. We observed that the intelligence on lighting dwindles down in the southern section where, as you know, the propaganda of this

7

organization and similar educational effort has not permeated as it has in the other sections. We also observed that the educational work loses in effect as the size of the town or community decreases; that you are reaching to a much greater degree, educating more efficiently, the industrial consumers of electrical service in the larger cities at the expense of those in the smaller communities. The same comparison holds true when the large and very large institutions are compared with the medium and small. The extent of ignorance or lack of enlightenment is very much greater for the latter.



Importance of Artificial Lighting to the Business According to the Judgement of the Men Interviewed

A—Vitally important......... 55.4%
B—Moderately important..... 31.6%
C—Of little importance....... 13.0%

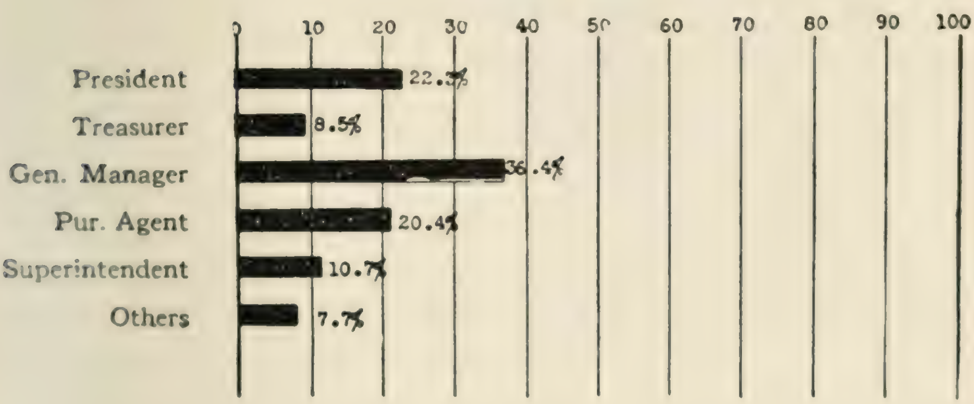
Fig. 4.

Coming to Fig. 4, we have here asked the executives of the industrial concerns their estimate or appraisal of the importance of artificial lighting in their business. We find that 55 per cent. recognize it as vitally important and a little less than one-third as moderately important, while the remainder state that it is of little importance to them.

What is the disposition of the industrial plant toward the proposition of buying light? Do they buy lighting or merely lamps and equipment? There is a distinct disposition to buy lighting as a general proposition. That is the most favorable observation that we have of the effect of educational work that has been done along this line. We have also made an analysis of the extent to which the industrial consumer gives the same attention to lighting problems as to power problems, the question being asked somewhat in this way, whether he would give as much or the same attention to lighting problems as to power problems,

or to the purchase of lamps and equipment as to the purchase of motors, generators or other electrically driven machinery. A small proportion would give more attention to the lighting problem than any other. Practically 58 per cent. consider that they would give as much attention to the lighting problem as to power, about one-fifth of the group will give somewhat less attention to lighting than to power, eleven and one-half per cent. would give considerably less attention to lighting problems. Here we have contrasted on the same proposition the large and very large concerns against the medium and small, showing the large extent to which the larger institutions would consider the lighting proposition.

Who Authorizes Changes in Lighting, Purchase and Installation of Equipment.



It will be seen from these percentages that generally speaking it is the executives who should be approached in regard to improvements in factory lighting.

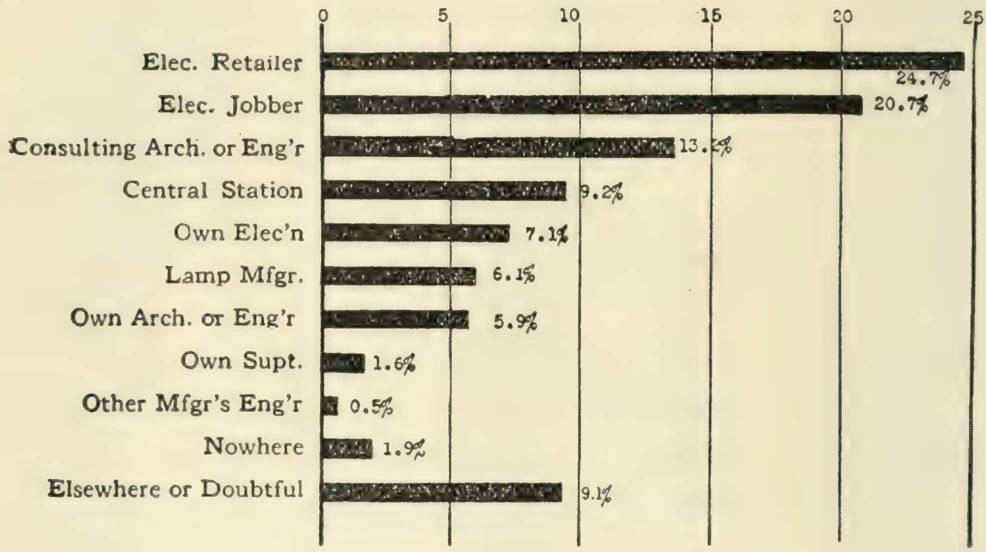
Fig. 5.

We have found upon careful analysis that the average cost for lighting throughout these 446 institutions scattered throughout fifteen states in summer was $216.00 per month, in winter $613.00 per month. These are quite significant figures.

I referred at the outset to the control of the lighting proposition within the average institution. Four per cent. represents the extent to which the superintendent is responsible for instal-

lation, the company's own architect or engineer in about 3 per cent., consulting architect or engineer in 3 per cent., the chief electrician of the plant in 35 per cent. of the instances, outside contractor in 63 per cent. This shows the domination on this particular feature of the outside contractor who is rivaled only by the chief electrician.

Where Manufacturer Would Seek Advice Regarding Lighting Changes.



Eliminating those who were doubtful as to whom they would consult on questions pertaining to the lighting of their plants, it was found that 72 per cent would go to the electrical distributor or someone in their own organization. This would seem to indicate that the electrical jobber and retailer are the factors dominating the situation.

Fig. 6.

Next is the responsibility for purchase of equipment or letting of contracts. See Fig. 5. It is fair to combine the first three bars as representing the chief executive's business. That would give some 60 per cent. of the instances for the president or general manager, purchasing agent 20 per cent., superintendent 10,

architect or engineer 2, others, a miscellaneous group, about 6 per cent.

Another parallel feature is the question as to where the consumer would seek advice regarding lighting changes, indicated in Fig. 6. We find the executive is quite ready to confess his ignorance on the lighting proposition or anything pertaining to the entire electrical development of his plant; nevertheless, he is keenly interested. He realizes to a considerable extent, if he is an intelligent executive, how important that proposition is to him. He will seek advice. Here is the field from which he will seek advice. First of all, is the electrical retailer. His domain of influence in that field is nearly 25 per cent.; second, is the jobber who scores 21 per cent., consulting architect or engineer, 13 per cent., central station 9.2 per cent., their own electrician 7 per cent., the lamp manufacturer 6 per cent., their own architect or engineer 5, practically 6 per cent., lamp manufacturer's engineer 4.5 per cent., own superintendent 1.6 per cent., architect engineer or electrician of some other manufacturer one-half of 1 per cent., their own opinion 2 per cent., doubtful 10 per cent.

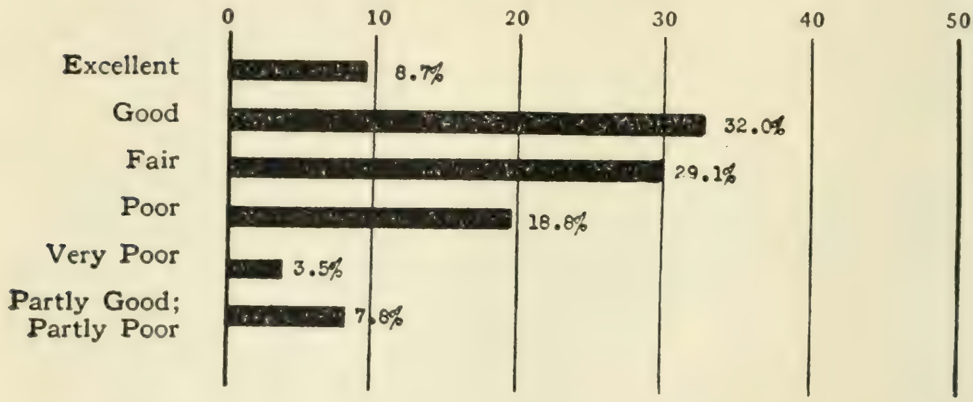
When it comes to the question of planning or laying out the lighting change or development we have as evidence the facts developed from the history of the latest actual change. In nearly 40 per cent. of the instances reported upon, the local dealer is found to be the party who laid out the change, the plant's own electrician in a little less than one-third of the instances, consulting architect or engineer in 13 per cent., own architect or engineer, 10 per cent., lamp manufacturer's engineer, 6 per cent., central station man 4 per cent.

A study of the proportion of these consumers who bought and produced their own lighting and power, shows that 69 per cent. of the plants visited buy their light and power, and that 37 per cent. produce part and buy part; that 47 per cent. of the plants visited keep their lighting expense separate from their power expense, while 53 per cent. do not. The percentages will total more than one hundred, owing to the comparatively small proportion that bought and produced their power.

Fig. 7 is perhaps the meat of the survey, the present condition of lighting as found in the various plants. A small group, a little less than 9 per cent., ranked as excellent. Than a trifle

less than one-third ranked as good, 29 per cent. fair, 18.8 per cent. poor, 3.5 per cent. very poor, 7.8 per cent. partly good and partly poor. Now with those figures before you, contrast with the condition found in the offices, of which 19 per cent. were

Investigator's Observation of Present Conditions of Lighting in Plants Visited.



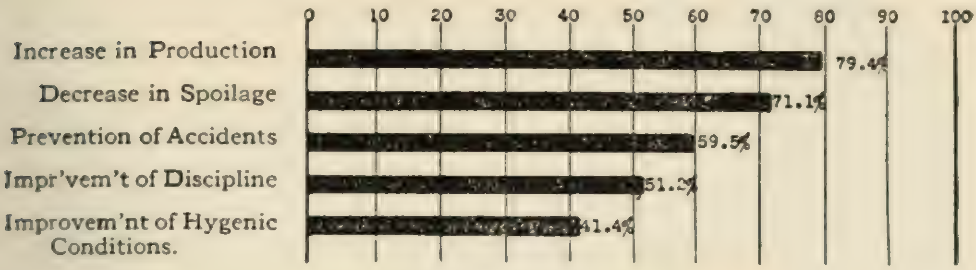
Only 40 per cent. of the manufacturing plants visited had lighting that could be considered good. Better illumination was needed in 60 per cent.

Fig. 7.

rated as excellent, 36 per cent. good, 31 per cent. fair and only 13 per cent. poor, none very poor. Even these ratings are conservative and are not based on the standards of intensity which lighting enginers are promoting today and which enginering research has proven necessary from the standpoint of efficiency production.

What are the things that interest and influence an industrial executive most when he comes to consider his lighting problems? Curiously, that is a question that almost any of us could venture a very intelligent estimate upon, but we want to know the answers specifically and not merely in general terms. We want to know not what are the important things, but what is the order of their importance. We have a very important analysis of that feature as expressed by industrial executives, and here it is in Fig. 8. The first and bigger consideration invariably is increase

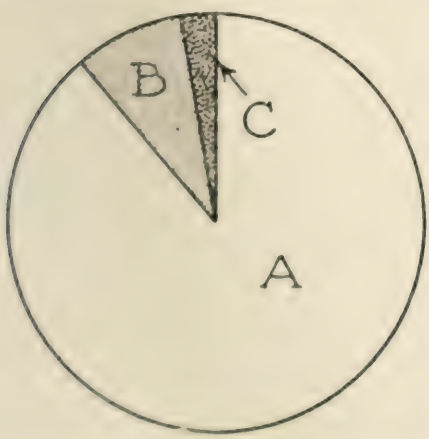
Appraisal by Manufacturers of Advantages to be Derived from Efficient Industrial Lighting.



Manufacturers who had good lighting appreciated its value largely from the standpoint of its stimulating effect on output.

Fig. 8.

in production, second, decrease in spoilage, third, prevention of accidents, fourth, improvement of discipline, fifth, improvement of hygienic conditions. A very peculiar feature of this is the even curve that this thing shows given on a point for point basis showing an 8, 7, 6, 5, 4 value that I think can be accomplished as a very good criterion as to the weight of these factors in selling the lighting proposition or in selling anything akin to the industrial field.



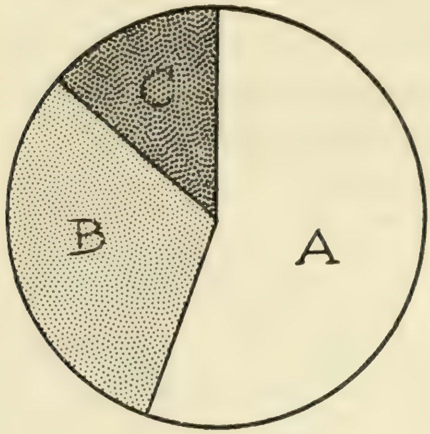
Familiarity with MAZDA B Lamps

A—Intelligently familiar 88.5%
B—Vaguely familiar 8.7%
C—Unfamiliar 2.7%

Fig. 9.

Just as a very good indication of how far publicity has reached the industrial consumer I am showing you these charts of familiarity with types of Mazda lamps. Figs. 9, 10 and 11. Here is the product that has been advertised to a greater extent than

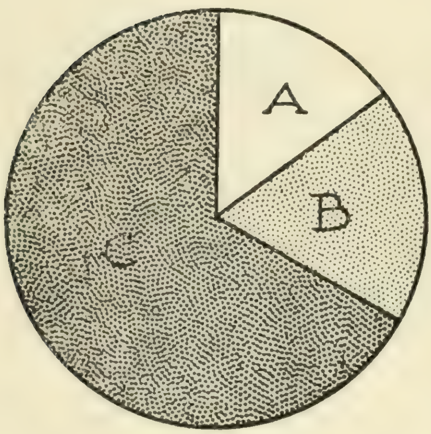
anything else in the electrical field, and we find when analyzing the familiarity with these types of lamps that only 88.5 per



Familiarity with MAZDA C Lamps

A—Intelligently familiar 61.3%
B—Vaguely familiar.......... 22.3%
C—Unfamiliar 16.4%

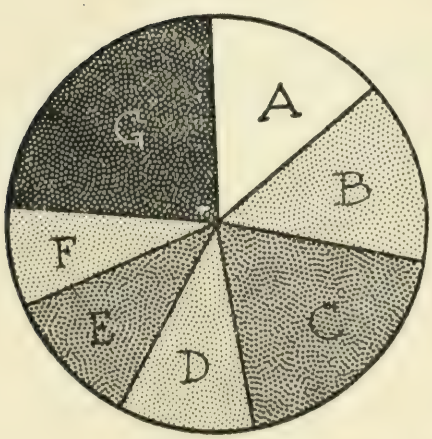
Fig. 10.



Familiarity with MAZDA C-2 Lamps

A—Intelligently familiar 15.2%
B—Vaguely familiar.......... 19.3%
C—Unfamiliar 65.5%

Fig. 11.



Time of change	Per cent. of plants
A—Within one year	14.6
B—One year ago	13.4
C—Two years ago	20.2
D—Three years ago	10.6
E—Four Years ago	11.1
F—Five years ago	5.9
G—More than five years ago ..	24.0

Fig. 12.

cent. confess themselves as familiar with Mazda B, 61 per cent. with Mazda C, and only 15 per cent. with Mazda C 2, or the

daylight lamp, familiarity meaning a little more than just recognition of the name or what it means by contact with and intelligence regarding it.

The question of the time of the last lighting change is of course of extreme significance on the basis of the fact that equipment more than five years old is very largely obsolete or obsolescent. In Fig. 12, area A represents changes within a year of the time the investigation was conducted, the early part of 1919; B a year old, C two years old, D three years old, E four years old, F five years old, and G more than five years old, giving us a total of practically 30 per cent., nearly one third that have lighting installations in which no change or modifica-nition of the name or what it means by contact with and intelligence regarding it.

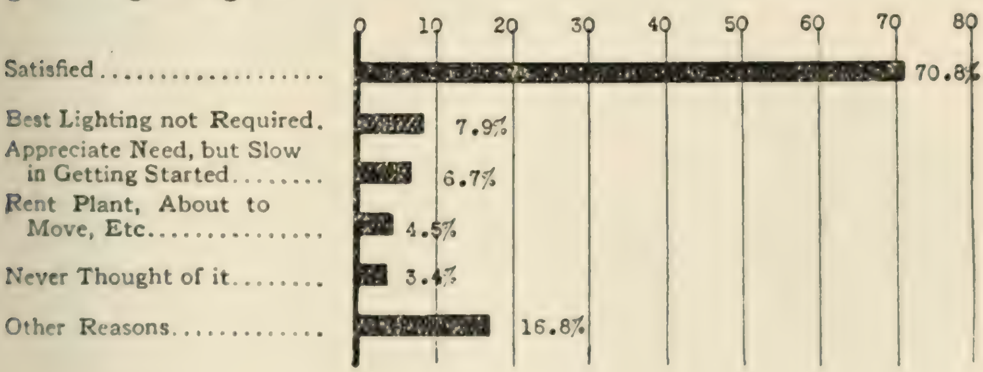


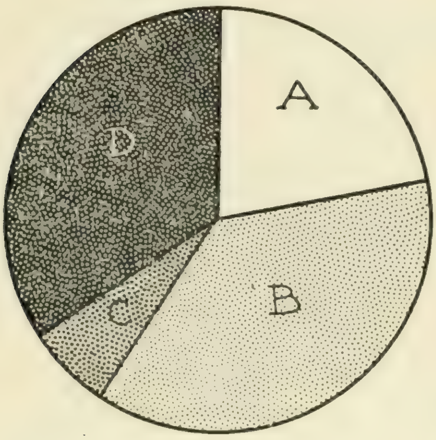
Fig. 13.

Why these improvements have not been made within the five years by the groups referred to is shown in Fig. 13, and the one great reason you will see is simply general satisfaction, lethargy or complacency on the part of the institution. A few say that the best lighting is not required and a few others that they appreciate the need but are slow in getting started. That is the usual group of procrastinators, the small group that are going to move, or something of that kind; a still smaller group who never thought of it, while about one-sixth give miscellaneous reasons. But the significant thing here is the large proportion who are simply satisfied. Now it is worth while to find out whether they had any right to be satisfied, and what kind of lighting did they have. We find that the condition of lighting can be improved on, because within that group there was not a single one ranked by investigators as excellent, there were 11 per cent. good, 39

per cent. fair, 41 per cent. poor and 9 per cent. very poor or 50 per cent. poor or very poor, nevertheless satisfied.

On the basis of how intelligently informed they are we find only 12 per cent. who are ranked by the investigator as being intelligently informed as to what efficient industrial lighting really was, 33 per cent. vaguely informed, but 55 per cent. were unhesitatingly not informed as to what efficient industrial lighting was. Nevertheless they are satisfied.

The investigators then went through the plant and made certain observations, the results of which are shown here. There is the proportion of industries in which the lamps were equipped with reflectors, one-sixth equipped entirely, about one-third largely equipped, a little less than one-third partly equipped and a little less than one-fifth not equipped at all with reflectors.



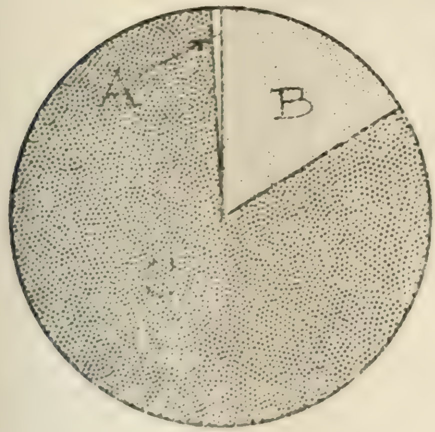
Cleaning

	Per cent. of plants
A—Cleaned regularly	22.4
B—Cleaned irregularly	37.3
C—Cleaned frequently	6.3
D—Cleaned infrequently	34.0

Fig. 14.

On the subject of the cleaning of lamps we find in Fig. 14, 22 per cent. who clean their lamps regularly, 37 per cent. who clean their lamps irregularly, 6 per cent. frequently, 34 per cent. infrequently, and a feature of interest to you will be the fact that after the investigator asked about this feature very frequently the executive would either give instruction at the time that this be done, that the lamps be cleaned regularly, or make a note to see that it was done. The thought had never occurred to him. That suggests a possibility for educational work on one small but doubtless effective feature by this association. In a very small proportion of the plants, less than one per cent. (see Fig. 15) a great many burned out lamps were found, in one-sixth of

the plants a few were found, but in a great majority, nearly 83 per cent. none were found. Spacing of lighting units was ranked as efficient in about one-sixth of the plants, as fairly good in some forty-three per cent. and as inefficient in 41 per cent.

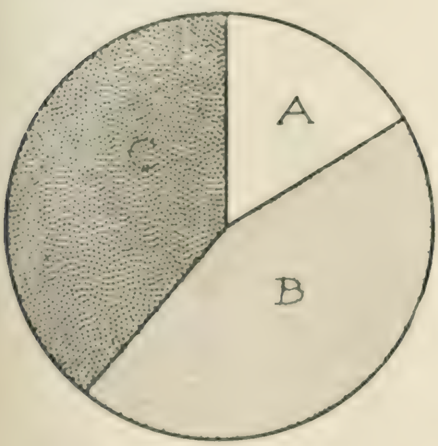


Observation of Burned-out Lamps

	Per cent. of plants
A—Many in	0.4
B—A few in	16.6
C—None in	82.8

Fig. 15.

In a trifle over 5 per cent. of the plants carbon lamps were found in a great many sockets, in a little more than one-fourth a few were found, while in 68 per cent. no carbon lamps were found.



Empty Sockets Observed in Plants

	Per cent. of plants
A—Many in	17
B—A few in	48
C—None in	35

Fig. 16.

Here we have (in Fig. 16) an illustration of the number of empty sockets found, a great many in 17 per cent. of the plants, a few in 48 per cent., and none at all in 35 per cent.

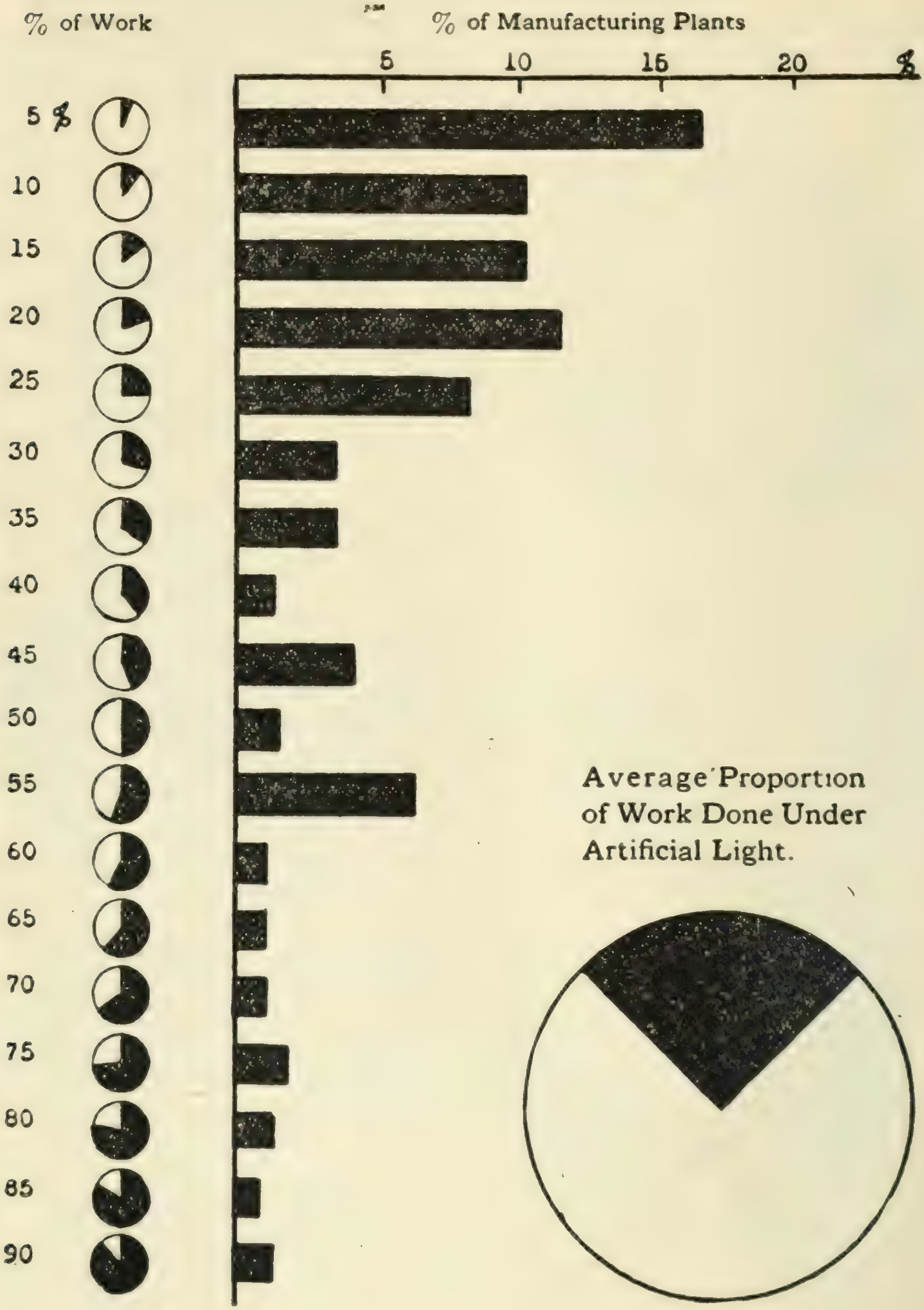

% of Work
% of Manufacturing Plants
5
10
15
20
%
5 %
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
Average Proportion of Work Done Under Artificial Light.

Fig. 17.

Fig. 17 gives an analysis of the amount of work done under artificial light throughout these plants which may be taken as typical of the condition throughout the country. The scale at the top represents the per cent. of plants and the little dials down at the side the proportion of work. In other words, that first group, the circle, shows that in some 17 per cent. of the plants 5 per cent. of the work was done under artificial light while the one at the bottom shows that in 2 per cent. of the plants 90 per cent. of the work was done under artificial light. There are a few exceptions to the downward curves as for example the 55 per cent. group is larger than the 45, otherwise it runs quite true to form. We find the condition in the average plant to be as illustrated here. Now average plant means something entirely different from the average for the entire group. This does not represent the average amount of work for the entire industrial group, but the condition of the average plant, get the distinction, 17½ per cent., striking a weighted average on the basis of this data at the left increases that area by one-half, in other words the general average for the entire group, for which perhaps a better figure for the amount of work done under artificial light is approximately 25 per cent.

In this analysis, I have simply tried to give you briefly some of the high lights of this investigation. We could give you a great many additional features, but these are the things that we thought would be of greatest interest to you. I think we may safely say that these conditions we have brought to you do represent average conditions. That is a bird's eye of the industrial field. It shows how much work there is to be done. It shows to some extent the character of the work to be done.

DISCUSSIONS.

Mr. Willcox: Mr. Chairman, I want to add my congratulation to the Society and to the firm that undertook this work. It is very comprehensive and complete data which they have gathered in a very interesting field of work. I don't know which to admire most, the cleverness in arranging this program or the willingness on the part of those interviewed to give the information. I would like to ask how much difficulty the investigators found in inducing the companies and men interviewed to give this information.

Such information could not be as readily obtained in England, owing to the general attitude of mind against disclosing such matters. I would also like to ask for the data showing how many of these installations used general overhead lighting as against local lighting and a combination of both.

MR. VINCENT: I would like to ask Mr. Eastman what per cent. of industries included in the survey had their own engineers.

MR. MACBETH: There is one question I want to ask, Mr. Eastman. In your tabulation of changes made during a certain period, did that go into detail? Was that taken grossly or did it mean the change of a few lamps?

MR. EASTMAN (in answer to MR. WILLCOX): As to how much trouble we experienced in obtaining this information, it simply parallels the question that I might ask any sales-manager who might be present as to how much trouble it is to sell goods. That is our business. That is the business of these men. They are trained and educated to get information as investigators. They have no trouble getting it on this or any other subject. If there is any comparison, any contrast, I would say that we had much less trouble in this industrial field than in others that we have undertaken. They are very willing to talk, very much interested in what we had to suggest to them, if anything, but at least interested in the improvement of their own conditions. Bear in mind there is no better educational work in the world than the Socratic method of education, which is question and answer. You are catechizing these people upon the condition of their light. It is worth ten times as much to them as individuals as it is to us. We do not care anything about the individual report. That is just one little sample that we are using in our mass analysis, but that man gets a great many suggestions because things are brought to his attention that he never thought or has not thought of for a long time. The trouble if any that we experienced is in getting away rather than in getting in.

In answering MR. VINCENT: We haven't any data as to the num-

ber of engineers. That question was not asked among the identifying features. Mr. Willcox's question as to the proportion of overhead lighting as against local lighting, 36 per cent., by and large, were overhead, general overhead; 25.4 per cent. local machine or bench lighting and 39.8 per cent. combination. If I am correct in answering what is in the gentleman's mind, it is a question as to whether the number of samples taken is sufficient to form the basis for a satisfactory criterion. I never expected to have that question asked me by a group of engineers. I have had to contend with it so often that I have talked it backwards and forwards, up and down, and in every direction, to manufacturers, and to sales managers, as to the necessity in all research work, in all scientific development of making qualitative, not quantitative analysis, and getting a distribution of samples rather that a vast mass of evidence as a basis for your final conclusions. That is what we have done. We had, however, answering the question, 446 intensive studies, each study requiring from three-quarters of an hour to an hour perhaps, some a little less than that, a case where the investigator studied the whole lighting proposition with the man, and the distribution as shown to you throughout the various types of industries, carefully distributed according to size, carefully distributed according to population strata, and every other consideration we could think of at the outset to give us a safe basis, because this sort of an investigation, bear in mind, has as its objective the sort of thing that necessitates care in the scientific work, and the one incentive is to produce a new scientific development in commercial research and in addition to that incentive is the fact constantly confronting you that somebody is going to spend a lot of money on the basis of what you take up and it has got to be right or a lot of money is going to be spent uselessly. I can vouch for the accuracy of the data that has been placed before you gentlemen.

(In answer to Mr. Macbeth): No. Any material change was taken into consideration, or any additions to a plant causing the change. There were two reasons for analyzing that feature. One was to determine what portion had made changes of that character. It was interesting to observe where the change was made through an addition, it was very frequently, while I can't

give you percentages of proportions, where through the necessity of a change, there was a modification of the lighting throughout the institution, this certainly would be the natural result. But any material change was taken into consideration, because we wanted also as a basis for the history of the work that was done in connection with that change.

NOTE.—A Survey of Industrial Lighting in Fifteen States. By R. O. Eastman, prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, October 20 to 23, 1919, Chicago, Ill.

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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XV | MARCH 20, 1920 | NO. 2

COEFFICIENTS OF UTILIZATION.*

BY WARD HARRISON AND EARL A. ANDERSON.

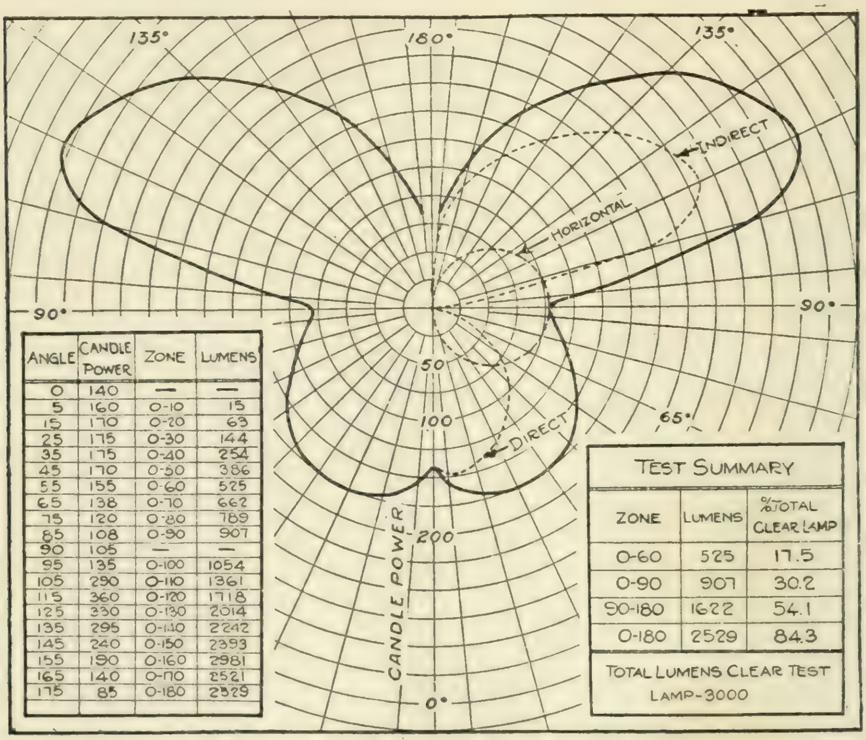
Synopsis: A method is presented for the direct determination of Coefficients of Utilization applying to installations of all ordinary types of lighting units in rooms of varied proportions and different ceiling and wall colors. As a basis for the method, Coefficient of Utilization data are tabulated from a series of several hundred illumination tests made in an experimental room with reflectors having three fundamental forms of light distribution. Illustrating the application of the data presented, typical Coefficient of Utilization Tables, as determined for a number of reflector types in common use, are included.

The variation in the percentage of light reaching the plane of illumination for three general types of lighting units, as found from an extended series of illumination tests in an experimental room whose size, ceiling height, outlet arrangement and interior color could be changed over a wide range, was reported by the authors before the Society in 1915.[1] From these data and the results of other subsequent similar tests, coefficient of utilization tables for candlepower distribution curves of three component types, called indirect, horizontal and direct, have been computed and are shown in Table 5 of this paper. The indirect component curve is similar in shape to that given by a standard type of totally indirect fixture. The direct component curve corresponds to the curve of an opaque direct reflector with a medium cut-off. The horizontal is a circular curve with the maximum candlepower at 90°; a distribution similar to that given by a standard vacuum tungsten lamp. Values are listed applying to rooms having ceiling and wall reflection factors from 0 per cent. to 80 per cent., and for varying proportions of room width to height from 0.5 to 5.0.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

[1] Illumination Efficiencies as Determined in an Experimental Room, I. E. S. TRANSACTIONS, Vol. XI, p. 67.

The plan of the Three-Curve Calculation Method for the determination of coefficients of utilization of all ordinary interior fixtures, as presented in this paper, consists simply in separating the curve of the test reflector into the three component curves; then the proportion of useful light flux is computed separately for the lumens in the indirect, horizontal and direct component curves by reference to the tables of coefficients of utilization for these component curves. This division of the test candlepower curve into the three components is shown graphically by the dotted candlepower curves in Fig. 1.



ANGLE	CANDLE POWER	ZONE	LUMENS
0	140	—	—
5	160	0-10	15
15	170	0-20	63
25	175	0-30	144
35	175	0-40	254
45	170	0-50	386
55	155	0-60	525
65	138	0-70	662
75	120	0-80	789
85	108	0-90	907
90	105	—	—
95	135	0-100	1054
105	290	0-110	1361
115	360	0-120	1718
125	330	0-130	2014
135	295	0-140	2242
145	240	0-150	2393
155	190	0-160	2981
165	140	0-170	2521
175	85	0-180	2529

TEST SUMMARY

ZONE	LUMENS	% TOTAL CLEAR LAMP
0-60	525	17.5
0-90	907	30.2
90-180	1622	54.1
0-180	2529	84.3

TOTAL LUMENS CLEAR TEST LAMP-3000

Fig. 1.—Separation of Test Candlepower Distribution Curve into Three Component Curves

The size of the horizontal component is determined by making its 90° angle candlepower equal to the candlepower at the 90° angle of the test distribution curve, which for the test curve of the light opal semi-indirect bowl in Fig. 1 is 105 candlepower. The total lumens represented by a circular curve, such as the horizontal component, equals very closely 10 times 90° candlepower,[2] or in this case, 10 x 105 = 1050, (lumens horizontal component).

[2] Mathematically, the total lumens in a symmetrical circular curve with the maximum at the horizontal or 90° axis = $\pi^2 \times$ (maximum candlepower), or 9.87 $\times$ 90° candlepower. Hence, for simplicity in determining the lumens to be placed in the horizontal component, 10 x 90° candlepower may be used with negligible error.

Subtracting the candlepower values of the horizontal component curve, indirect and direct components remain as shown by the dotted curves. The actual number of lumens represented in the indirect component is found by subtracting the lumens of the horizontal component in the 90°-180° zone from the total 90°-180° lumens for the test curve; in this instance,

$$1622 - \frac{1050}{2} = 1097 \text{ (lumens indirect component).}$$

Similarly, the direct component is found by subtracting the lumens of the horizontal component in the 0°-90° zone from the test curve total for this zone, or

$$907 - \frac{1050}{2} = 382 \text{ (lumens direct component).}$$

The lumens in the three component curves whose algebraic sum equals the original test curve are then:

Indirect	1097
Horizontal	1050
Direct	382
Total	2529

Suppose the ceiling has a 60 per cent. reflection factor, the walls 40 per cent. and the room dimensions such that the room ratio is 1.25, then by finding the coefficient of utilization values for the component curves in Table 5 applying under these conditions, and multiplying the lumens in each component curve by the respective coefficient, the useful lumens are found to be:

Indirect	1097 x .25 = 274
Horizontal	1050 x .30 = 315
Direct	382 x .65 = 248
Total useful lumens	837

But reference to the data on the candlepower distribution curve sheet shows that the clear lamp used in making the test emitted 3,000 lumens,[3] hence the coefficient of utilization of the lighting system under the assumed conditions of the installation is:

[3] Where the output efficiency of the reflector instead of the lumen output of the test lamp is shown on the test curve sheet, the coefficient of utilization may be found from the useful lumens by: Coefficient of utilization = useful lumens × reflector output efficiency divided by total lumens (0°-180°) of test curve.

$$\frac{\text{Useful lumens}}{\text{Lumens clear lamp}} = \frac{837}{3000} = 0.279.$$

Obviously, in case the candlepower at 90° is zero the horizontal component will have a zero value, and the lumen quantities for the direct and indirect components will be the same respectively as the 0°-90° and 90°-180° lumen values of the test curve.

In some instances the subtraction of the horizontal component will leave a negative direct or indirect component, as in the distribution curve of the diffusing globe with reflector shown in Fig.

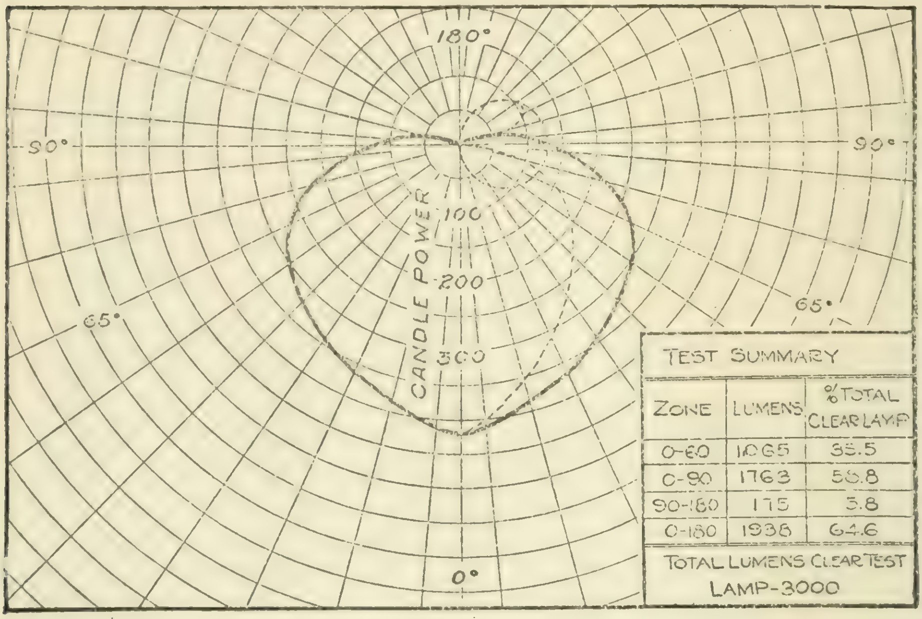


Fig. 2.—Test Candlepower Distribution Curve Showing Negative Indirect Component Curve.

2. In these instances the calculation is carried through precisely as before, except that the useful lumens for the negative components are added algebraically, that is, subtracted in obtaining the sum of useful lumens for the three components. Thus, a calculation of the coefficient of utilization for the reflector curve of Fig. 2 under the same installation conditions as those assumed in the previous example is as follows:

The horizontal component is $10 \times 130 = 1300$ lumens.

Then the indirect is $175 - \frac{1300}{2} = -475$ (negative).

And the direct is $1762 - \frac{1300}{2} = 1112$.

Calculating the useful lumens for the component curves as in the previous example,

Indirect	−475 x .25 =	−119	(negative)
Horizontal	1300 x .30 =	390	
Direct	1112 x .65 =	723	
Total useful lumens		994	

$$\text{Coefficient of utilization} = \frac{994}{3000} = 0.331.$$

Classification of Direct Component Curves.—The shapes of the direct and indirect component curves remaining after the subtraction of the horizontal curve are subject to variation, depending upon the distribution of light flux in the original test curves. This difference in curve shape is of less importance in the case of the indirect component since for reflector systems of semi-indirect and indirect types in which the indirect component represents a large part of the flux, the hanging height of the reflectors is commonly adjusted so as to secure a fairly even distribution of light on the ceiling with but little direct light against the side walls, and under this condition the proportion of useful flux is not greatly affected.

For the direct component it is obvious that a broad or narrow shape of distribution curve may influence the proportion of useful light flux to a very considerable extent. Especially in the case of small rooms with dark walls a fairly broad direct component curve may have a coefficient of utilization several per cent. lower than that which applies to a medium curve; and similarly, a rather narrow curve may have a coefficient of utilization several per cent. higher than the value for a medium curve.

In order to provide for a more precise calculation of the coefficient for these exceptional curves, broad and narrow classes of direct component curves were established from an analysis of a

large number of reflector distribution curves. The typical[4] curves chosen for the broad and narrow classes, are shown on the left hand side of Fig. 3 above and below the medium curve. Coefficient of utilization values computed for these broad and narrow classes in comparison with the medium curve used in the test series, are shown in light face type in Table 5. The first or lesser light face value in each column applies to the broad, and the last and higher light face figure to the narrow direct component class. The distribution curves shown on the right hand side of Fig. 3 are pointed shapes, all three of which at first glance might appear to fall in the narrow class, but which are better placed in the classes as shown. This classification of the direct component curves into broad, medium and narrow will be found to apply to practically all common types except distribution curves with the light flux concentrated in very narrow zones, as in the case of special units of projector types.

Actual experience indicates that the coefficient of utilization values for the medium direct component, shown in bold face type in Table 5, may be applied, in the computations for the large majority of practical installations, without serious error; for example, a comparison of the direct component of the test curve in Fig. 1, with the typical curves of Fig. 3, shows that it really falls in the narrow class, though the medium direct component coefficient value was used in working out the example. Referring to Table 5, a coefficient of .69 is found to apply to the narrow direct component under the room conditions assumed, instead of .65, the value for the medium curve. Recalculating the useful lumens for the direct component in Fig. 1 gives a result of

[4] The classification of the direct component curves as broad, medium and narrow is an arbitrary one based on the percentage of flux in the 0°-40° zone, considering the 0°-90° flux as 100 per cent. The flux in the 0°-40° zone is practically the amount that becomes useful in a black-walled room with a single outlet where the width of the room is 1.5 times the height of the lamp above the reference plane.

For the typical component curve classes selected, the

$$\frac{\text{lumens in } 0^\circ - 40^\circ \text{ zone}}{\text{lumens in } 0^\circ - 90^\circ \text{ zone}} \text{ are } \begin{cases} \text{Broad} = 35\% - 40\% \\ \text{Medium} = 40\% - 45\% \\ \text{Narrow} = 45\% - 50\% \end{cases}$$

Hence, although it is usually evident from inspection whether the direct component is broad, medium, or narrow, the classification may be determined by calculation from the following equation:

$$\text{Per cent. of flux in } 0\text{-}40^\circ \text{ zone} = \frac{(\text{Total lumens in } 0^\circ - 40^\circ \text{ zone—}0.65 \text{ (cp @ } 90^\circ))}{(\text{Total lumens in } 0^\circ - 90^\circ \text{ zone—}5.0 \text{ (cp @ } 90^\circ))}.$$

The last terms in the numerator and denominator of this expression are simply the number of lumens in the 0° - 40° and the 0° - 90° zones for the horizontal component curve, and it is noted that these terms disappear when there is no horizontal component.

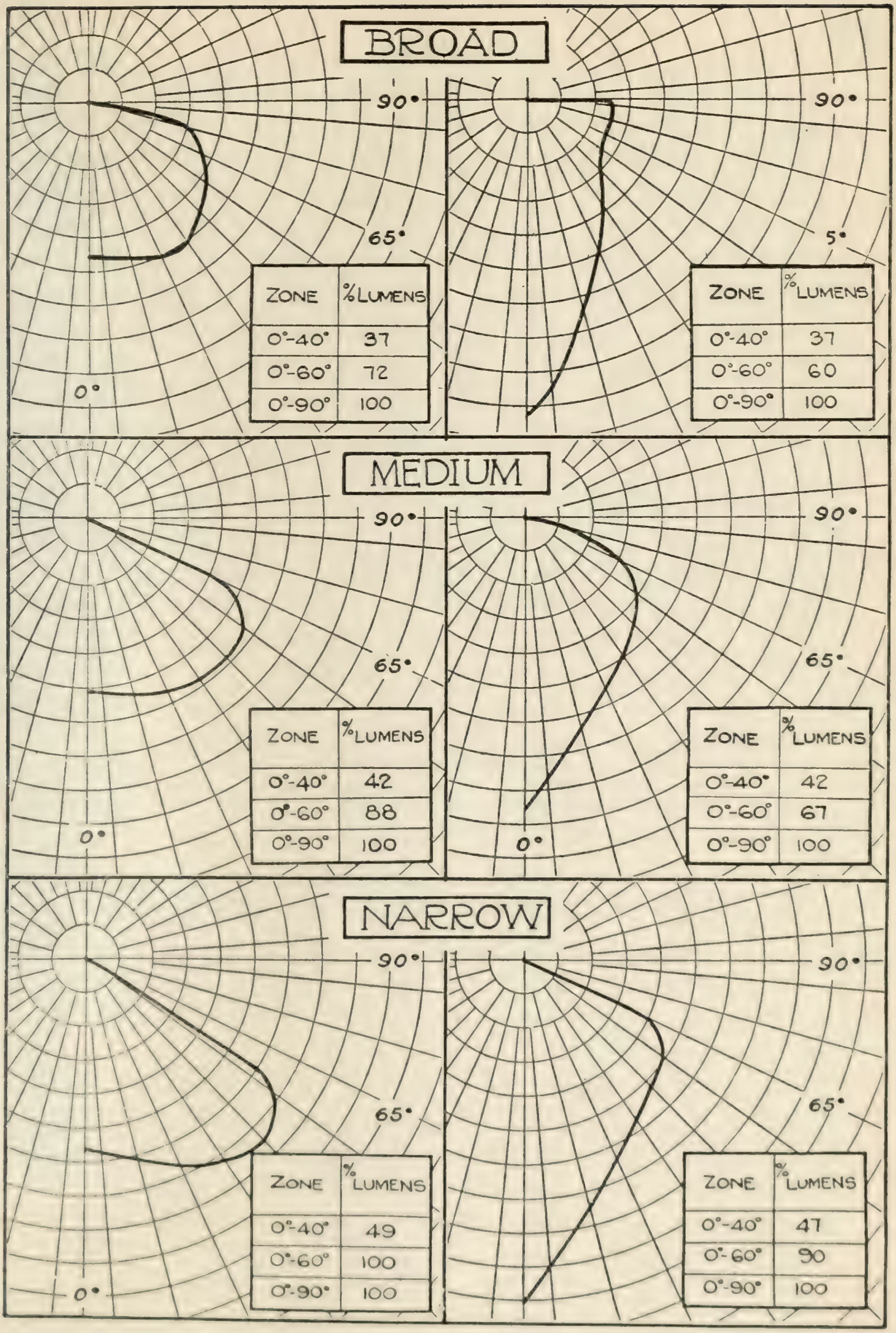


Fig. 3.—Types of Candlepower Distribution Curves Falling in Broad, Medium and Narrow Direct Component Classes.

$$382 \times .69 = 264,$$

and using this in obtaining the sum of useful lumens, the coefficient of utilization is determined to be 0.284, a difference of only 0.005 from the value 0.279 found in the previous calculation.

Room Ratio.—It has been shown that the proportion of light which reaches the useful plane is the same for rooms of similar proportions, but that the amount may vary greatly, according to the width of the room compared with the height of the light sources. This variation resultant from the difference in room proportions is taken account of in Table 5 by showing coefficients of utilization applying to a series of room ratios ranging from 0.5 to 5.0.[5] These room ratios represent approximately the room width divided by the ceiling height. However, in order to take account of the wide difference in the proportionate height of the plane of work above the floor, and the variation of hanging height for lighting fixtures in high rooms, the following expressions were used in classifying the proportions of the installation.

1. For reflector systems of direct types in which the lighting unit is the principal source of light,

$$\text{Room ratio} = \frac{\text{Room width}}{2\ (\text{height from plane of work to lamps})}.$$

2. For indirect and semi-indirect systems where the ceiling becomes the principal source of light,

$$\text{Room ratio} = \frac{\text{Room width}}{1\ 1/3\ (\text{height from plane of work to ceiling})}.$$

It will be noted that the room ratios found by these different methods are exactly the same for an ordinary ceiling height of 12 ft., with lamps mounted 9 ft. from the floor and with a plane of work 3 ft. from the floor.

Rectangular Rooms.—The coefficient of utilization values in Table 5 apply directly to square rooms. However, the floor areas in most rooms are rectangular in shape rather than square. Tests reported in Table 1 were performed to indicate differences in the coefficients of utilization for rooms of fixed ceiling height but varied in proportion from a square to a rectangle whose length is six times its width. Quite commonly, for the purpose of de-

[5] The proportions of the rooms in which the tests from which the tables were calculated were varied from a minimum room ratio of 0.8 to a maximum of 4.15, and the test curves were extrapolated to obtain the values for room ratios outside of this range.

termining the coefficient of utilization for a rectangular room, the room has been considered as equivalent to a square room whose side equaled the average of the width and length of the rectangle. Another plan has been to consider the coefficient of utilization for the rectangular room to be the average of the coefficients applying to two square rooms whose sides were equal respectively to the long and narrow dimensions of the rectangular room. A third method, which consists in finding the coefficient of utilization for a square room of the narrow dimension and adding to it one-third of the difference between this value and the coefficient for a square room of the long dimension, is proposed, and according to the comparative values as computed from the component curve tables shown for the test room conditions in Table 1, this scheme gives values most closely approximating the actual test results. In extremely long narrow rooms the other two methods are likely to give far too high a value for the coefficient.

TABLE I.

COMPARATIVE COEFFICIENT OF UTILIZATION VALUES FOR SQUARE AND RECTANGULAR ROOMS AS FOUND BY TEST AND BY CALCULATION METHODS.

Ceiling height 7 ft. Test plane 3 ft. from floor. Lamps mounted 3 ft. above test plane. Outlets spaced 4.5 ft. x 4.5 ft. Ceiling 64 per cent. Floor 14 per cent. reflection factor.

			Room Dimensions (feet)			
Reflector	Wall color		4.5×4.5 (1×1)	4.5×9 (1×2)	4.5×13.5 (1×3)	4.5×27.0 (1×6)
Bare lamp	Black (4%)	..Test	15.1	19.8	22.4	24.9
(Curve EE		Method A. ..	15.3	22.2	27.0	37.6
Fig. 4)		Difference .	+0.2	+2.4	+4.6	+12.7
		Method B. ..	15.3	21.1	24.9	31.7
		Difference .	+0.2	+1.3	+2.5	+6.8
		Method C. ..	15.3	19.2	21.5	26.2
		Difference .	+0.2	−0.6	−0.9	+1.3

TABLE I. (Continued).

Bare lamp	White (81%)	Test	41.1	47.5	49.6	51.2
		Method A. ..	42.9	50.1	55.1	64.6
		Difference .	+1.8	+2.6	+5.5	+13.4
		Method B. ..	42.9	49.5	52.3	57.1
		Difference .	+1.8	+2.0	+2.7	+5.9
		Method C. ..	42.9	47.3	49.2	52.5
		Difference .	+1.8	—0.2	—0.4	+1.3
Steel Bowl (Curve AA Fig. 4)	Black (4%)	Test	29.0	33.5	34.6	38.3
		Method A. ..	27.9	35.6	39.8	48.6
		Difference .	—1.1	+2.1	+5.2	+10.3
		Method B. ..	27.9	33.9	36.9	40.9
		Difference .	—1.1	+0.4	+2.3	+2.6
		Method C. ..	27.9	31.8	33.9	36.5
		Difference .	—1.1	—1.7	—0.7	—1.8
Steel Bowl	White (81%)	Test	43.3	48.2	49.0	50.2
		Method A. ..	43.6	50.2	52.5	58.0
		Difference .	+0.3	+2.0	+3.5	+7.8
		Method B. ..	43.6	48.1	50.0	52.3
		Difference .	+0.3	—0.1	+1.0	+2.1
		Method C. ..	43.6	46.6	47.8	49.4
		Difference .	+0.3	—1.6	—1.2	—0.8

Method A.—Coefficient for rectangular room taken to be the same as for a square room whose side is the average of the dimensions of the rectangular room.

Method B.—Coefficient for rectangular room taken as the average of the coefficients for square rooms of the long and narrow dimensions respectively.

Method C.—Coefficient for rectangular room taken as coefficient for square room of narrow dimension plus one-third of difference between this value and the coefficient for a square room of the long dimension.

Ceiling and Wall Reflection Factors.—The increase in the coefficient due to light-colored ceilings, as shown in Table 5, is of course widely different, depending upon the percentage of light which reaches the ceiling directly from the lighting units; the increment is, however, directly proportional to the ceiling reflection factor. On the other hand, the increment in the coefficient due to the effect of light walls, is not proportional to the change in wall reflection factor, but is much greater, for instance, in going from 60 to 80 per cent. than from 0 to 20 per cent. This results from the fact that much of the light striking the walls must undergo multiple reflection before reaching the reference plane, as was described in detail in the preliminary report of these tests. This phenomenon largely accounts for the rather common opinion that light walls do not have an important effect in increasing the amount of illumination, especially since even a good light-colored paint which would give a reflection factor of 70 per cent. on a uniform surface such as the ceiling, might only result in an average reflection factor for the walls of 50 per cent. or less, when the areas included by the windows, doors, dark-colored pictures, etc., in small rooms, and the light interference from supporting columns in larger rooms are taken into consideration.

Sample charts showing the percentage reflection factor for different colors of paints and papers are of a considerable assistance in the accurate determination of the proper coefficient, in avoiding the possibility of a wrong estimate of the reflection factors. In the many instances where there is a choice of suitable finishes of rather similar appearance, such color charts are of decided advantage in planning an installation of the highest efficiency consistent with the color tones desired.

Effect of Floor Reflection.—The tests from which the tables of coefficients of utilization for the component curves were computed, were performed in rooms having oak floors whose reflection factor was approximately 14 per cent. This is of the order of the prevailing reflection factor of floors in most interiors. It has been found that even where there is a light-colored floor its effect in increasing the coefficient of utilization is small, and ordinarily the effect can be neglected when determining the coefficient of utilization unless the walls and ceiling are light in color also. In the latter condition the white floor may increase the

effective illumination to an important extent in large sized rooms. Table 2 is included, showing the results of illumination tests with white floors in a small and also a medium sized room with different wall and ceiling reflection factors.

TABLE II.

FACTORS FOR TAKING ACCOUNT OF EFFECT OF FLOOR REFLECTION ON COEFFICIENT OF UTILIZATION.

(Calculated from Coefficient of Utilization tests in small and medium sized rooms, with varied floor reflection factor.)

Reflection factors		Room width	Floor reflection factor			
Ceiling	Walls	Ceiling height	0%	14%[6]	40%	80%
0%	0%	1.0	1.00	1.00	1.00	1.00
		2.0	1.00	1.00	1.00	1.00
	40%	1.0	1.00	1.00	1.00	1.00
		2.0	1.00	1.00	1.01	1.02
	80%	1.0	1.00	1.00	1.00	1.01
		2.0	0.99	1.00	1.02	1.04
40%	0%	1.0	1.00	1.00	1.00	1.01
		2.0	0.99	1.00	1.02	1.04
	40%	1.0	1.00	1.00	1.01	1.03
		2.0	0.99	1.00	1.03	1.07
	80%	1.0	0.98	1.00	1.03	1.08
		2.0	0.97	1.00	1.05	1.13
80%	0%	1.0	1.00	1.00	1.01	1.02
		2.0	0.99	1.00	1.03	1.08
	40%	1.0	0.99	1.00	1.02	1.05
		2.0	0.98	1.00	1.05	1.12
	80%	1.0	0.97	1.00	1.06	1.15
		2.0	0.95	1.00	1.09	1.22

Arrangement of Lighting Units.—The coefficient of utilization values for the component curves in Table 5 are based on test installations where the ratio of the distance between lamps to the mounting height above the plane of work, is from 1.5 to 2.0, the

[6] The coefficient of utilization values for component curves, Table 5, are based on tests in rooms with 14 per cent. floor reflection factor.

maximum order of spacing ratio that has been found to give reasonably uniform illumination for interior lighting units under the conditions obtaining in the usual installation. From the results of a number of illumination tests by different investigators, including those that were made by the authors in the experimental room, it is evident that a greater average illumination of the order of 10 per cent. to 15 per cent. is possible when using a center-of-room arrangement of lamps in comparison with a distributed system of outlets. However, even though higher coefficients of utilization would apply to the center-or-room arrangement of outlets and to installation spacing ratios exceeding the values above, the apparent gain is usually more than counterbalanced by the need for an increased average illumination in order to bring the minimum intensity to the same value as with lamp spacings which give greater uniformity.

Photometer Test Plate.—The coefficient of utilization values in the table for component curves were all obtained with a Weber photometer using a standard transmitting test plate. Test plates of this type are known to give a result several per cent. lower than the true value, as a result of the imperfect diffusion of the glass. Most photometers in common use for illumination work have this standard type of test plate and hence installations designed by this method would show comparable test results with such illuminometers. Subsequent to the performance of most of the tests it became possible to secure a photometer test plate designed to compensate for this error, such as was described before the Society in 1915.[7] Using this test plate, a number of tests with different types of reflectors in a room 13½ ft. by 27 ft., height 9 ft., were repeated under different conditions as to wall colors. With the compensated test plate the average increase in illumination for different forms of light distribution and wall colors was 4.0 per cent. The difference ranged from 2 per cent. to 7 per cent., and, as might be expected, the larger occurred where there were white walls and reflector types giving high candlepowers at angles near the horizontal.

Accuracy of Three-Curve Calculation Method.—As an indication of the order of accuracy to be expected in the calculation of coefficients of utilization by the three-curve method, data are

[7] Sharp and Little, I. E. S. TRANSACTIONS, Vol. X, page [illegible].

shown in Table 3 giving the actual coefficients found by illumination tests in comparison with the values found by the three-curve calculation method for eight reflector type distribution curves illustrated in Fig. 4.

TABLE III.

Comparison of coefficients of utilization as obtained by illumination tests and by three curve calculation method.

Room A.—13.5 ft. x 13.5 ft., ceiling 14 ft. Test plane 3 ft. from floor. One unit mounted 8½ ft. above test plane.

Room C.—13.5 ft. x 27 ft., ceiling 9 ft. Test plane 3 ft. from floor. Eight units spaced 4.5 ft. x 4.5 ft. and mounted 4⅓ ft. above test plane.

		Room A	Room C					
	Ceiling	64%		33%			64%	
	Walls	42%	4%	42%	81%	4%	42%	81%
Reflector	Test	34.5	43.5	48.5	52.4	45.0	50.0	56.4
AA	Calc.	35.4	43.5	46.7	52.8	43.6	48.0	54.9
	Diff.	+0.9	0.0	—1.8	+0.4	—1.4	—2.0	—1.5
Reflector	Test	38.6	Not Tested			49.4	56.2	65.6
BB	Calc.	40.0	——	——	——	49.4	55.4	64.8
	Diff.	+1.4	——	——	——	0.	—0.8	—0.8
Reflector	Test	34.7	42.7	49.7	59.9	45.7	54.6	67.8
CC	Calc.	35.8	42.3	47.8	58.3	44.8	52.8	65.3
	Diff.	+1.1	—0.4	—1.9	—1.6	—0.9	—1.8	—2.5
Reflector	Test	29.7	35.8	42.6	51.6	38.7	47.8	59.0
DD	Calc.	31.5	36.1	40.9	49.8	38.9	46.0	56.9
	Diff.	+1.8	+0.3	—1.7	—1.8	+0.2	—1.8	—2.1
Bare Lamp	Test	25.3	27.3	36.5	48.3	32.6	44.8	59.7
EE	Calc.	25.1	27.4	34.7	47.8	32.3	42.8	59.7
	Diff.	—0.2	+0.1	—1.8	—0.5	—0.3	—2.0	0.
Reflector	Test	25.8	27.1	33.0	39.2	35.2	43.6	52.8
FF	Calc.	27.8	26.4	30.2	36.8	34.5	40.6	50.2
	Diff.	+2.0	—0.7	—2.8	—2.4	—0.7	—3.0	—2.6
Reflector	Test	17.2	15.1	17.7	22.3	24.5	29.0	38.2
GG	Calc.	18.2	13.9	16.7	21.5	23.5	28.7	36.5
	Diff.	+1.0	—1.2	—1.0	—0.8	—1.0	—0.3	—1.7
Reflector	Test	16.7	12.1	14.9	18.0	22.7	28.8	35.7
HH	Calc.	16.8	11.4	13.8	18.0	22.0	27.0	34.5
	Diff.	+0.1	—0.7	—1.1	0.	—0.7	—1.8	—1.2

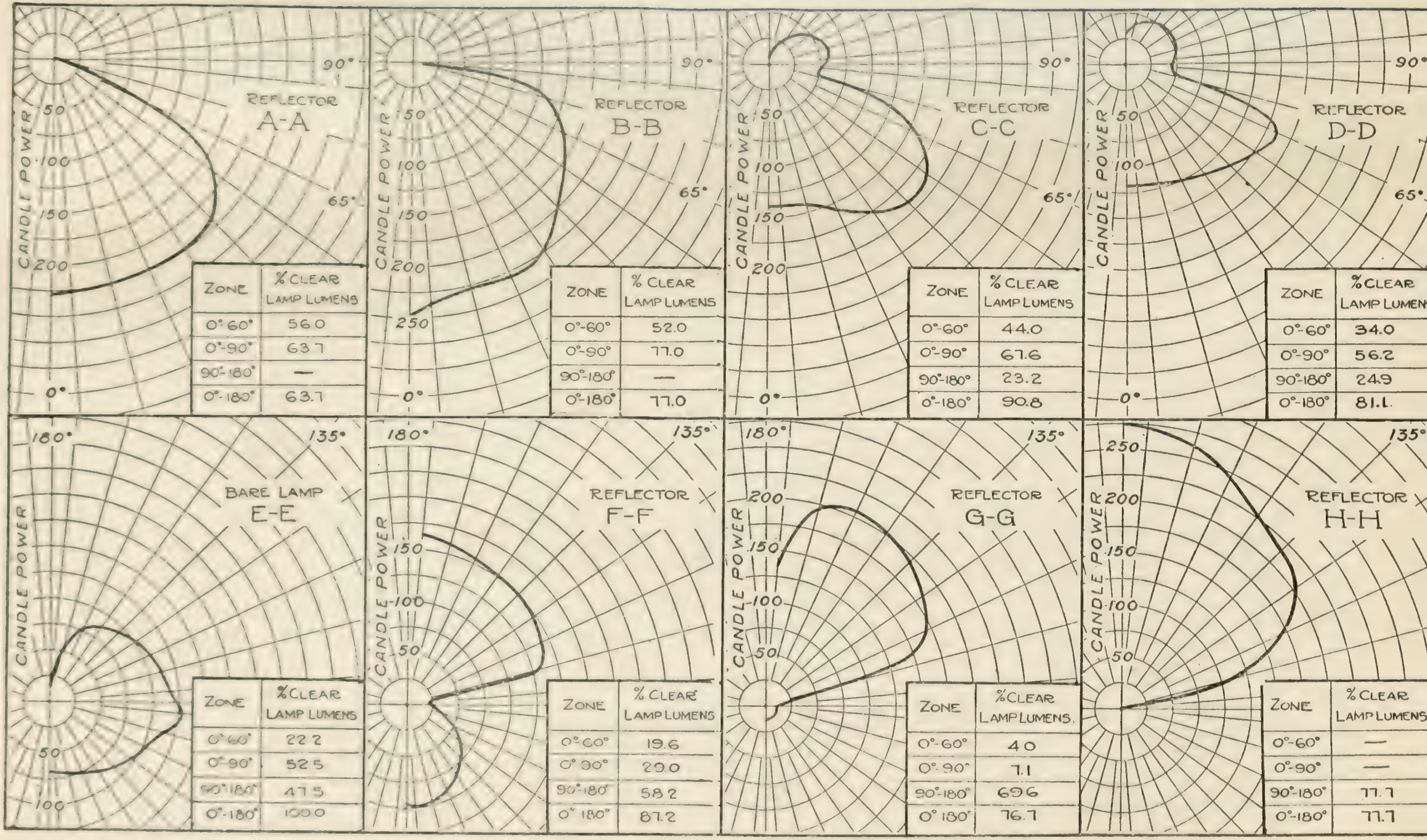


Fig. 4.—Candlepower Distribution Curves of Lighting Units in Table III.

These tests were performed using the same experimental room apparatus that was developed for the basic tests. The reflector systems tested were chosen as having light distributions fairly representative of the various types characteristic for interior lighting equipments, and the differences found in these tests are hardly greater than the individual test variations that might be expected to occur in using illuminometers.

However, as previously mentioned, it is not to be expected that the method presented will give accurate results for installations of equipment giving light concentrated in extremely narrow zones, as for example refractor or projector units, and in the case of installations departing widely from the usual conditions of spacing, hanging height, etc.

TABLES OF COEFFICIENT OF UTILIZATION VALUE FOR DIFFERENT REFLECTOR SYSTEMS.

Illustrating a practical application of the three-curve method, Tables 4 and 4b list coefficients of utilization calculated for twenty reflector systems assuming the distribution curves as shown. In using coefficient of utilization values from such tables in the familiar formula for determining the lamp size necessary in designing an installation,

$$\text{lumens per lamp} = \frac{\text{footcandles} \times \text{depreciation factor} \times \text{area in square feet}}{\text{number of lamps} \times \text{coefficient of utilization}}$$

An allowance of from 1.20 to 1.30 for the depreciation factor to take care of the loss in footcandle intensity from lamp aging, dust collection and depreciation of reflecting surfaces, is not believed to be too high for ordinary direct reflectors, and from 1.30 to even 1.40 is believed to be necessary for equipment having open inverted bowls or reflectors such as semi-indirect and indirect types, depending of course upon the installation and maintenance conditions. Even these maximum values are less than those which tests by different investigators have shown to exist in some lighting installations which had been in service for a considerable period, and in instances where special attention had not been given to the maintenance work.

TABLE 4a

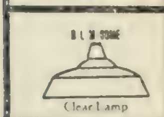
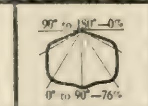
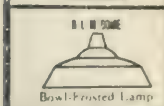
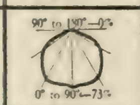
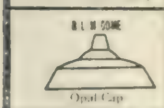
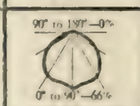
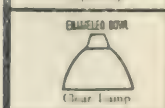
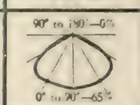
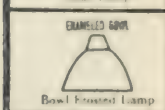
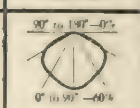
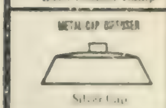
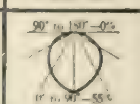
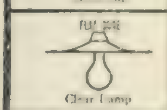
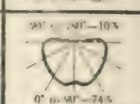
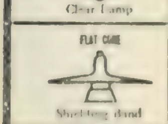
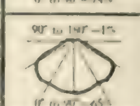
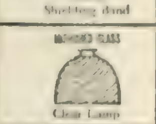
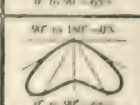
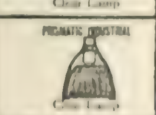
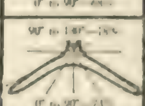
Color (Reflecting Value) of	Ceiling		Light (70%)			Medium (50%)		Dark (30%)
	Walls		Light (50%)	Medium (35%)	Dark (20%)	Medium (35%)	Dark (20%)	Dark (20%)
Reflector Type	Light Output	Room Ratio	Coefficients of Utilization					
		1	.46	.43	.41	.42	.40	.40
		1½	.54	.51	.48	.50	.47	.47
		2	.60	.57	.54	.56	.53	.53
		3	.65	.62	.60	.61	.59	.59
		5	.69	.67	.65	.66	.65	.64
		1	.45	.42	.40	.41	.39	.38
		1½	.52	.49	.47	.48	.46	.46
		2	.56	.53	.51	.52	.50	.50
		3	.62	.60	.57	.58	.56	.56
		5	.66	.65	.63	.63	.62	.62
		1	.40	.37	.35	.37	.34	.34
		1½	.47	.44	.42	.44	.42	.42
		2	.51	.48	.46	.48	.46	.46
		3	.56	.54	.52	.53	.51	.51
		5	.60	.58	.57	.57	.56	.55
		1	.38	.36	.34	.35	.33	.33
		1½	.45	.43	.41	.42	.40	.40
		2	.49	.47	.45	.46	.44	.44
		3	.54	.52	.50	.51	.49	.49
		5	.59	.57	.55	.56	.54	.54
		1	.37	.34	.32	.33	.31	.31
		1½	.43	.40	.38	.39	.37	.37
		2	.46	.44	.42	.43	.41	.41
		3	.51	.49	.47	.48	.46	.46
		5	.55	.53	.52	.52	.51	.50
		1	.33	.31	.30	.31	.29	.29
		1½	.39	.37	.35	.36	.34	.34
		2	.43	.41	.39	.40	.38	.38
		3	.47	.45	.43	.44	.42	.42
		5	.50	.49	.47	.48	.47	.46
		1	.36	.31	.28	.30	.28	.27
		1½	.44	.39	.36	.37	.35	.35
		2	.50	.46	.42	.44	.41	.41
		3	.56	.53	.48	.51	.47	.47
		5	.62	.59	.54	.57	.53	.53
		1	.38	.36	.34	.35	.33	.33
		1½	.44	.42	.40	.41	.39	.39
		2	.49	.47	.45	.46	.44	.44
		3	.54	.52	.50	.51	.49	.49
		5	.58	.56	.55	.55	.54	.53
		1	.44	.41	.39	.41	.39	.38
		1½	.50	.47	.45	.47	.45	.44
		2	.55	.52	.50	.52	.50	.49
		3	.59	.57	.55	.56	.54	.54
		5	.63	.61	.59	.59	.58	.58
		1	.46	.42	.39	.40	.37	.36
		1½	.54	.50	.47	.48	.45	.44
		2	.60	.56	.53	.54	.51	.50
		3	.67	.64	.61	.61	.58	.56
		5	.73	.70	.67	.67	.64	.62

TABLE 4b

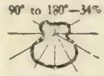
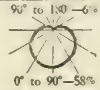
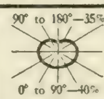
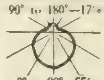
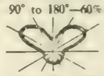
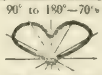
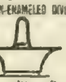
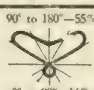
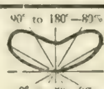
Color (Reflecting Value) of Ceiling			Light (70%)			Medium (50%)		Dark (30%)
Color (Reflecting Value) of Walls			Light (50%)	Medium (35%)	Dark (20%)	Medium (35%)	Dark (20%)	Dark (20%)
Reflector Type	Light Output	Room Ratio	Coefficients of Utilization					
LIGHT DENSITY OPAL  Bowl-Frosted Lamp	90° to 180°—34%  0° to 90°—51%	1 1½ 2 3 5	.34 .41 .47 .53 .59	.31 .38 .44 .50 .56	.28 .35 .41 .47 .53	.29 .35 .40 .45 .50	.26 .33 .38 .43 .48	.24 .30 .35 .40 .45
DENSE OPAL  Bowl-Frosted Lamp	90° to 180°—20%  0° to 90°—60%	1 1½ 2 3 5	.40 47 .52 .58 .62	.37 .44 .48 .55 .60	.34 .41 .46 .52 .58	.35 .42 .46 .52 .57	.33 .39 .43 .49 .55	.32 .38 .42 .47 .52
DIFFUSING GLOBE  With Reflector	90° to 180°—6%  0° to 90°—58%	1 1½ 2 3 5	31 37 42 47 .51	.28 .34 .39 .44 49	.26 .32 .37 .42 .46	.28 .33 .38 .43 .48	.25 .31 .36 .41 .46	.25 .31 .36 .41 .45
DIFFUSING GLOBE  Light Opal	90° to 180°—35%  0° to 90°—40%	1 1½ 2 3 5	.23 .30 .35 .41 .48	.20 .26 .31 .37 .44	.17 .23 .28 .34 .41	.18 .24 .28 .33 .39	.16 .21 .25 .30 .36	.14 .19 .22 .26 .31
SHALLOW REFLECTOR  Diffusing Bowl	90° to 180°—20%  0° to 90 60%	1 1½ 2 3 5	.32 .40 .45 .52 .59	.28 .36 .41 .47 .54	.26 .33 .38 .44 .51	.27 .34 .39 .45 .51	.25 .32 .37 .42 .48	.23 .30 .35 .40 .46
ONE-PIECE UNIT  Reflector and Bowl	90° to 180°—17%  0° to 90°—55%	1 1½ 2 3 5	.32 .39 .44 49 .54	.28 .35 .40 .45 .50	.26 .33 .38 .43 .48	.28 .34 .39 .44 .49	.25 .31 .36 .41 .46	.25 .30 .35 .40 .45
SEMI-INDIRECT  Light Opal	90° to 180°—60%  0° to 90°—25%	1 1½ 2 3 5	.27 .34 .39 45 51	.24 .30 .35 41 .47	.21 .27 .32 .38 44	.20 .25 .29 .34 .40	.17 .22 .26 .31 .37	.14 .18 .21 .25 .29
SEMI-INDIRECT  Dense Opal	90° to 180°—70%  0° to 90°—10%	1 1½ 2 3 5	.24 .30 .34 .39 45	.21 .27 .31 .36 .42	.19 .24 .28 .33 .39	.16 .20 .23 .27 .32	.14 .18 .21 .25 .30	.10 .13 .15 .18 .21
PORCELAIN-ENAMELED INVERTED  Diffusing Plate Bottom	90° to 180°—55%  0° to 90°—16%	1 1½ 2 3 5	.25 .30 .34 .38 43	.22 .27 .31 .36 41	.20 .25 .29 .34 .40	.18 .22 .25 .29 .33	.17 .21 .24 .28 .32	.14 .17 .19 .22 .24
INDIRECT  Clear Lamp	90° to 180°—80%  0° to 90°—0%	1 1½ 2 3 5	.22 .27 .31 .36 .42	19 .24 .28 .33 .39	.17 .22 .26 .31 .37	.14 .17 .20 .24 .28	.12 .15 .18 .22 .26	.07 .09 .11 .13 .16

TABLE V.—COEFFICIENTS OF UTILIZATION FOR COMPONENT CANDLEPOWER CURVES.

Ceiling Reflection Factor 0%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	03	04	05	06	07	09	11	13	16
	Dir.	19 24 29	20 25 30	23 27 31	25 29 33	28 32 36	33 36 39	37 40 43	41 44 47	48 50 52
0.60	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	06	07	08	09	10	12	14	17	20
	Dir.	28 33 38	29 34 39	32 36 40	34 38 42	37 41 45	41 44 47	45 48 51	49 52 55	56 58 60
0.70	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	08	09	10	11	13	15	17	20	23
	Dir.	35 40 45	36 41 46	39 43 47	41 45 49	44 48 52	48 51 54	52 55 58	56 59 62	62 64 66
0.80	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	09	10	11	12	14	16	19	22	25
	Dir.	41 46 51	42 47 52	44 48 52	46 50 54	48 52 56	52 55 58	55 58 61	59 62 65	65 67 69
0.90	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	10	11	12	13	15	17	20	23	26
	Dir.	45 50 55	46 51 56	48 52 56	49 53 57	51 55 59	54 57 60	57 60 63	61 64 67	67 69 71
1.00	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	11	12	13	14	16	18	21	24	27
	Dir.	48 53 58	49 54 59	51 55 59	52 56 60	53 57 61	56 59 62	59 62 65	62 65 68	68 70 72
1.10	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	12	13	14	15	17	19	22	25	28
	Dir.	50 55 60	51 56 61	53 57 61	54 58 62	55 59 63	58 61 64	60 63 66	63 66 69	69 71 73
1.25	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	13	14	15	16	18	20	23	26	29
	Dir.	53 58 63	54 59 64	56 60 64	57 61 65	58 62 66	61 64 67	63 66 69	66 69 72	71 73 75
1.50	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	15	16	17	18	20	22	25	28	31
	Dir.	57 62 67	58 63 67	60 64 68	61 65 69	62 66 69	65 68 71	67 70 73	70 73 76	74 76 78
1.75	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	17	18	19	20	22	24	26	29	32
	Dir.	61 66 70	62 67 70	64 68 71	65 69 72	66 70 73	69 72 75	71 74 76	73 76 78	76 78 80
2.00	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.9
	Hor.	19	20	21	22	24	26	28	30	33
	Dir.	64 69 73	65 70 73	67 71 74	68 72 75	69 73 76	71 74 76	73 76 78	75 78 80	78 80 82
2.25	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	21	22	23	24	25	27	29	31	34
	Dir.	67 72 75	68 73 76	70 74 77	71 75 78	73 76 78	74 77 79	75 78 80	78 80 82	80 82 83
2.50	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	22	23	24	25	26	28	30	32	35
	Dir.	70 74 77	71 75 78	72 76 78	74 77 79	75 78 80	76 79 81	78 80 82	79 81 83	81 83 84
3.00	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	25	26	27	28	29	30	32	34	36
	Dir.	73 77 79	74 77 79	75 78 80	76 79 81	77 80 82	79 81 83	80 82 83	81 83 84	83 85 86
3.50	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	27	27	28	29	30	31	33	35	37
	Dir.	76 79 81	76 79 81	78 80 82	79 81 83	80 82 83	81 83 84	82 84 85	84 85 86	85 87 88
4.00	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	29	29	30	30	31	32	34	36	38
	Dir.	78 81 83	79 81 83	80 82 84	81 83 84	82 84 85	83 85 86	84 86 87	86 87 88	87 88 89
5.00	Ind.	.0	.0	.0	.0	.0	.0	.0	.0	.0
	Hor.	31	31	32	32	33	34	35	36	38
	Dir.	81 83 84	81 83 84	82 84 85	83 85 86	84 86 87	85 86 87	86 87 88	87 88 89	88 89 90

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 10%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.01	.01	.02	.02	.02	.02	.03	.04	.04
	Hor.	04	05	06	07	08	10	12	15	19
	Dir.	19 24 29	21 26 31	24 28 32	26 30 34	29 33 37	34 37 40	38 41 44	42 45 48	49 51 53
0.60	Ind.	.02	.02	.02	.03	.03	.03	.04	.04	.04
	Hor.	07	08	09	10	11	13	16	19	23
	Dir.	28 33 38	30 35 40	33 37 41	35 39 43	38 42 46	42 45 48	46 49 52	50 53 56	57 59 61
0.70	Ind.	.02	.02	.02	.03	.03	.03	.04	.04	.05
	Hor.	09	10	11	12	14	16	19	22	26
	Dir.	35 40 45	36 41 46	39 43 47	41 45 49	44 48 52	48 51 54	52 55 58	56 59 62	63 65 67
0.80	Ind.	.02	.02	.03	.03	.03	.04	.04	.05	.05
	Hor.	10	11	12	13	15	17	20	24	28
	Dir.	41 46 51	42 47 52	44 48 52	46 50 54	48 52 56	52 55 58	55 58 61	59 62 65	66 68 70
0.90	Ind.	.02	.03	.03	.03	.04	.04	.04	.05	.05
	Hor.	11	12	13	14	16	19	22	25	29
	Dir.	45 50 55	46 51 56	48 52 56	49 53 57	51 55 59	54 57 60	57 60 63	61 64 67	68 70 72
1.00	Ind.	.03	.03	.03	.04	.04	.04	.05	.05	.06
	Hor.	12	13	14	15	17	20	23	26	30
	Dir.	48 53 58	49 54 59	51 55 59	52 56 60	53 57 61	56 59 62	59 62 65	63 66 69	69 71 73
1.10	Ind.	.03	.03	.03	.04	.04	.04	.05	.05	.06
	Hor.	13	14	15	16	18	21	24	27	31
	Dir.	50 55 60	51 56 61	53 57 61	54 58 62	55 59 63	58 61 64	61 64 67	65 68 71	70 72 74
1.25	Ind.	.03	.03	.04	.04	.04	.05	.05	.06	.06
	Hor.	15	16	17	18	20	23	26	29	33
	Dir.	53 58 63	54 59 64	56 60 64	57 61 65	58 62 66	61 64 67	64 67 70	67 70 73	72 74 76
1.50	Ind.	.03	.04	.04	.04	.05	.05	.05	.06	.06
	Hor.	17	18	19	20	22	25	28	31	35
	Dir.	57 62 67	58 63 67	60 64 68	61 65 69	62 66 69	65 68 71	67 70 73	70 73 76	75 77 79
1.75	Ind.	.04	.04	.04	.05	.05	05	.06	.06	.07
	Hor.	19	20	21	22	24	27	30	33	36
	Dir.	61 66 70	62 67 70	64 68 71	65 69 72	66 70 73	69 72 75	71 74 76	73 76 78	77 79 81
2.00	Ind.	.04	.04	.05	.05	.05	.06	.06	.07	.07
	Hor.	21	22	23	24	26	28	31	34	37
	Dir.	64 69 73	65 70 73	67 71 74	68 72 75	69 73 76	72 75 77	73 76 78	75 78 80	79 81 83
2.25	Ind.	.04	.05	.05	.05	.06	.06	.06	.07	.07
	Hor.	23	24	25	26	28	30	32	35	38
	Dir.	67 72 75	68 73 76	70 74 77	71 75 78	73 76 78	75 78 80	76 79 81	78 80 82	81 83 85
2.50	Ind.	.05	.05	.05	.06	.06	.06	.07	.07	.08
	Hor.	25	26	27	28	30	32	34	36	39
	Dir.	70 74 77	71 75 78	72 76 78	74 77 79	75 78 80	77 80 82	79 81 83	80 82 84	82 84 86
3.00	Ind.	.05	.05	.06	.06	.06	.07	.07	.07	.08
	Hor.	27	28	29	30	32	34	36	38	40
	Dir.	74 77 79	74 77 79	75 78 80	76 79 81	77 80 82	80 82 84	81 83 84	82 84 85	84 86 87
3.50	Ind.	.05	.06	.06	.06	.07	.07	.07	.08	.08
	Hor.	29	30	31	32	33	35	37	39	41
	Dir.	76 79 81	76 79 81	78 80 82	79 81 83	80 82 83	82 84 85	83 85 86	84 86 87	86 88 89
4.00	Ind.	.06	.06	.06	.07	.07	.07	.08	.08	.08
	Hor.	31	32	33	34	35	36	38	40	42
	Dir.	78 81 83	79 81 83	80 82 84	81 83 84	82 84 85	83 85 86	84 86 87	86 87 88	88 89 90
5.00	Ind.	.06	.06	.07	.07	.07	.08	.08	.08	.09
	Hor.	33	34	35	36	37	38	39	41	43
	Dir.	81 83 84	81 83 84	82 84 85	83 85 86	84 86 87	86 87 88	87 88 89	88 89 90	89 90 91

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 20%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.02	.03	.03	.04	.04	.04	.05	.06	.07
	Hor.	04	05	06	07	10	12	14	17	21
	Dir.	19 24 29	21 26 31	24 28 32	26 30 34	29 33 37	34 37 40	38 41 44	42 45 48	49 51 53
0.60	Ind.	.03	.04	.04	.05	.05	.06	.07	.08	.09
	Hor.	08	09	10	11	13	15	18	22	26
	Dir.	28 33 38	30 35 40	33 37 41	35 39 43	38 42 46	42 45 48	46 49 52	50 53 56	57 59 61
0.70	Ind.	.04	.04	.05	.05	.06	.06	.07	.08	.10
	Hor.	10	11	12	13	15	17	20	24	28
	Dir.	35 40 45	37 42 47	40 44 48	42 46 50	45 49 53	49 52 55	53 56 59	57 60 63	63 65 67
0.80	Ind.	.04	.05	.05	.06	.06	.07	.08	.09	.10
	Hor.	11	12	13	14	16	19	22	26	30
	Dir.	41 46 51	42 47 52	44 48 52	46 50 54	49 53 57	53 56 59	56 59 62	60 63 66	66 68 70
0.90	Ind.	.05	.05	.06	.06	.07	.07	.08	.09	.11
	Hor.	12	13	14	16	18	21	24	28	32
	Dir.	45 50 55	46 51 56	48 52 56	50 54 58	52 56 60	55 58 61	58 61 64	62 65 68	68 70 72
1.00	Ind.	.05	.06	.06	.07	.07	.08	.09	.10	.11
	Hor.	13	14	15	17	19	22	25	29	33
	Dir.	48 53 58	49 54 59	51 55 59	52 56 60	54 58 62	57 60 63	60 63 66	64 67 70	70 72 74
1.10	Ind.	.06	.06	.07	.07	.08	.08	.09	.10	.12
	Hor.	14	15	16	18	20	23	26	30	34
	Dir.	50 55 60	51 56 61	53 57 61	54 58 62	56 60 64	59 62 65	62 65 68	66 69 72	71 73 75
1.25	Ind.	.06	.07	.07	.08	.08	.09	.10	.11	.12
	Hor.	16	17	18	20	22	25	28	32	36
	Dir.	53 58 63	54 59 64	56 60 64	57 61 65	59 63 67	62 65 68	65 68 71	68 71 74	73 75 77
1.50	Ind.	.07	.07	.08	.08	.09	.09	.10	.11	.13
	Hor.	18	19	21	23	25	28	31	34	38
	Dir.	57 62 67	58 63 67	60 64 68	61 65 69	63 67 70	66 69 72	68 71 74	71 74 77	76 78 80
1.75	Ind.	.07	.08	.08	.09	.09	.10	.11	.12	.13
	Hor.	20	21	23	25	27	30	33	36	40
	Dir.	61 66 70	62 67 70	64 68 71	65 69 72	67 71 74	70 73 76	72 75 77	74 77 79	78 80 82
2.00	Ind.	.08	.09	.09	.10	.10	.11	.12	.13	.14
	Hor.	22	23	25	27	29	32	35	38	41
	Dir.	64 69 73	65 70 73	67 71 74	68 72 75	70 74 77	73 76 78	74 77 79	76 79 81	80 82 84
2.25	Ind.	.09	.09	.10	.10	.11	.11	.12	.13	.14
	Hor.	24	25	27	29	31	33	36	39	42
	Dir.	67 72 75	68 73 76	70 74 77	71 75 78	74 77 79	76 79 81	77 80 82	79 81 83	82 84 86
2.50	Ind.	.09	.10	.10	.11	.11	.12	.13	.14	.15
	Hor.	26	27	28	30	32	34	37	40	43
	Dir.	71 75 78	72 76 79	73 77 79	75 78 80	76 79 81	78 81 83	80 82 84	81 83 85	84 86 87
3.00	Ind.	.10	.11	.11	.12	.12	.13	.13	.14	.15
	Hor.	29	30	31	33	35	37	39	42	45
	Dir.	75 78 80	75 78 80	76 79 81	77 80 82	78 81 83	80 83 85	82 84 85	83 85 86	86 88 89
3.50	Ind.	.11	.11	.12	.12	.13	.13	.14	.15	.16
	Hor.	31	32	33	35	37	39	41	43	46
	Dir.	77 80 82	77 80 82	79 81 83	80 82 84	81 83 84	83 85 86	84 86 87	85 87 88	88 89 90
4.00	Ind.	.12	.12	.13	.13	.14	.14	.15	.15	.16
	Hor.	33	34	35	36	38	40	42	44	47
	Dir.	79 82 84	80 82 84	81 83 85	82 84 85	83 85 86	84 86 87	85 87 88	87 88 89	89 90 91
5.00	Ind.	.12	.13	.13	.14	.14	.15	.15	.16	.17
	Hor.	36	37	38	39	40	42	44	46	48
	Dir.	82 84 85	82 84 [illegible]	83 85 86	84 86 87	85 87 88	87 88 89	88 89 90	89 90 91	90 91 92

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 30%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.04	.04	.05	.05	.06	.07	.08	.09	.11
	Hor.	05	06	07	08	10	12	15	19	24
	Dir.	19 24 29	21 26 31	24 28 32	26 30 34	29 33 37	34 37 40	38 41 44	43 46 49	50 52 54
0.60	Ind.	.05	.05	.06	.06	.07	.08	.09	.11	.13
	Hor.	08	09	10	11	13	16	19	23	28
	Dir.	28 33 38	30 35 40	33 37 41	35 39 43	38 42 46	43 46 49	47 50 53	51 54 57	58 60 62
0.70	Ind.	.06	.06	.07	.07	.08	.09	.10	.12	.14
	Hor.	11	12	13	14	16	19	22	26	31
	Dir.	35 40 45	37 42 47	40 44 48	42 46 50	45 49 53	49 52 55	53 56 59	57 60 63	64 66 68
0.80	Ind.	.06	.07	.07	.08	.09	.10	.11	.13	.15
	Hor.	12	13	14	16	18	21	24	28	33
	Dir.	41 46 51	42 47 52	45 49 53	47 51 55	50 54 58	54 57 60	57 60 63	61 64 67	67 69 71
0.90	Ind.	.07	.07	.08	.09	.10	.11	.12	.14	.16
	Hor.	13	14	16	18	20	23	26	30	35
	Dir.	45 50 55	46 51 56	48 52 56	50 54 58	52 56 60	56 59 62	59 62 65	63 66 69	69 71 73
1.00	Ind.	.08	.08	.09	.10	.11	.12	.13	.15	.17
	Hor.	14	15	17	19	21	24	27	31	36
	Dir.	48 53 58	49 54 59	51 55 59	53 57 61	55 59 63	58 61 64	61 64 67	65 68 71	71 73 75
1.10	Ind.	.09	.09	.10	.10	.11	.12	.13	.15	.17
	Hor.	15	16	18	20	22	25	28	32	37
	Dir.	50 55 60	51 56 61	53 57 61	55 59 63	57 61 65	60 63 66	63 66 69	66 69 72	72 74 76
1.25	Ind.	.09	.10	.11	.11	.12	.13	.14	.16	.18
	Hor.	17	18	20	22	24	27	30	34	39
	Dir.	53 58 63	54 59 64	56 60 64	57 61 65	59 63 67	62 65 68	65 68 71	68 71 74	74 76 78
1.50	Ind.	.10	.11	.12	.12	.13	.14	.15	.17	.19
	Hor.	20	21	23	25	27	30	33	36	41
	Dir.	57 62 67	58 63 67	60 64 68	61 65 69	63 67 70	66 69 72	69 72 75	72 75 78	77 79 81
1.75	Ind.	.11	.12	.13	.13	.14	.15	.16	.18	.20
	Hor.	22	23	25	27	29	32	35	38	43
	Dir.	61 66 70	62 67 70	64 68 71	65 69 72	67 71 74	70 73 76	72 75 77	75 78 80	79 81 83
2.00	Ind.	.12	.13	.14	.14	.15	.16	.17	.19	.21
	Hor.	24	25	27	29	31	34	37	40	45
	Dir.	64 69 73	65 70 73	67 71 74	68 72 75	70 74 77	73 76 78	75 78 80	77 80 82	81 83 85
2.25	Ind.	.13	.14	.15	.15	.16	.17	.18	.19	.21
	Hor.	26	27	29	31	33	36	39	42	47
	Dir.	67 72 75	68 73 76	70 74 77	71 75 78	74 77 79	76 79 81	77 80 82	80 82 84	83 85 87
2.50	Ind.	.14	.15	.16	.16	.17	.18	.19	.20	.22
	Hor.	28	29	31	33	35	38	41	44	49
	Dir.	71 75 78	72 76 79	73 77 79	75 78 80	77 80 82	78 81 83	80 82 84	82 84 86	85 87 88
3.00	Ind.	.16	.16	.17	.17	.18	.19	.20	.21	.23
	Hor.	31	32	34	36	38	40	43	46	50
	Dir.	75 78 80	75 78 80	76 79 81	77 80 82	79 82 84	81 83 85	82 84 85	84 86 87	87 89 90
3.50	Ind.	.17	.17	.18	.18	.19	.20	.21	.22	.24
	Hor.	33	34	36	38	40	42	45	48	51
	Dir.	77 80 82	77 80 82	79 81 83	80 82 84	82 84 85	83 85 86	84 86 87	86 88 89	89 90 91
4.00	Ind.	.18	.18	.19	.19	.20	.21	.22	.23	.24
	Hor.	36	37	38	40	42	44	46	49	52
	Dir.	79 82 84	80 82 84	81 83 85	82 84 85	84 86 87	85 87 88	86 88 89	88 89 90	90 91 92
5.00	Ind.	.19	.19	.20	.21	.21	.22	.23	.24	.25
	Hor.	39	40	41	42	44	46	48	50	53
	Dir.	82 84 85	82 84 85	83 85 86	84 86 87	86 88 89	88 89 90	89 90 91	90 91 92	91 92 93

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 40%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.05	.05	.06	.06	.07	.08	.10	.12	.15
	Hor.	05	06	07	08	11	14	17	21	26
	Dir.	19 24 29	21 26 31	24 28 32	26 30 34	29 33 37	34 37 40	38 41 44	43 46 49	50 52 54
0.60	Ind.	.07	.07	.08	.09	.10	.11	.13	.15	18
	Hor.	08	09	11	12	14	17	21	25	30
	Dir.	28 33 38	30 35 40	33 37 41	35 39 43	38 42 46	43 46 49	47 50 53	52 55 58	59 61 63
0.70	Ind.	.08	.08	.09	.10	.11	.12	.14	.16	.19
	Hor.	11	12	14	15	17	20	24	29	34
	Dir.	35 40 45	37 42 47	40 44 48	42 46 50	45 49 53	49 52 55	53 56 59	58 61 64	65 67 69
0.80	Ind.	.09	.09	.10	.11	.12	.13	.15	.17	.20
	Hor.	12	13	15	17	19	22	26	31	36
	Dir.	41 46 51	42 47 52	45 49 53	47 51 55	50 54 58	54 57 60	57 60 63	62 65 68	68 70 72
0.90	Ind.	.10	.10	.11	.12	.13	.14	.16	.18	.21
	Hor.	14	15	17	19	21	24	28	33	38
	Dir.	45 50 55	46 51 56	49 53 57	51 55 59	53 57 61	57 60 63	60 63 66	64 67 69	70 72 74
1.00	Ind.	.11	.11	.12	.13	.14	.15	.17	.19	.22
	Hor.	15	16	18	20	22	25	29	34	39
	Dir.	48 53 58	49 54 59	52 56 60	53 57 61	55 59 63	59 62 65	62 65 68	66 69 72	72 74 76
1.10	Ind.	.12	.12	.13	.14	.15	.16	.18	.20	.23
	Hor.	16	18	20	22	24	27	31	36	41
	Dir.	50 55 60	51 56 61	54 58 62	55 59 63	57 61 65	60 63 66	63 66 69	67 70 73	73 75 77
1.25	Ind.	.13	.13	.14	.15	.16	.18	.20	.22	.24
	Hor.	18	20	22	24	26	29	33	38	43
	Dir.	53 58 63	54 59 64	57 61 65	58 62 66	60 64 68	63 66 69	66 69 72	69 72 75	75 77 79
1.50	Ind.	.14	.15	.16	.17	.18	.19	.21	.23	.25
	Hor.	21	23	25	27	29	32	36	40	45
	Dir.	57 62 67	58 63 67	61 65 69	62 66 70	64 68 71	67 70 73	70 73 76	73 76 79	78 80 82
1.75	Ind.	.15	.16	.17	.18	.19	.20	.22	.24	.26
	Hor.	23	25	27	29	32	35	39	43	47
	Dir.	61 66 70	62 67 71	65 69 72	66 70 73	68 72 75	71 74 77	73 76 78	76 79 81	80 82 84
2.00	Ind.	.17	.18	.19	.20	.21	.22	.24	.26	.27
	Hor.	25	27	29	31	34	37	41	45	49
	Dir.	64 69 73	65 70 73	68 72 75	69 73 76	71 75 78	74 77 79	75 78 80	79 81 83	82 84 86
2.25	Ind.	.18	.19	.20	.21	.22	.23	.25	.27	.28
	Hor.	27	29	31	33	36	39	43	47	51
	Dir.	67 72 75	68 73 76	71 75 78	72 76 79	75 78 80	77 80 82	78 81 83	81 83 85	84 86 88
2.50	Ind.	.19	.20	.21	.22	.23	.24	.26	.28	.29
	Hor.	29	31	33	35	38	41	45	48	52
	Dir.	71 75 78	72 76 79	74 78 80	76 79 81	78 81 83	79 82 84	81 83 85	83 85 87	86 88 89
3.00	Ind.	.21	.22	.23	.24	.25	.26	.27	.29	.30
	Hor.	32	34	36	39	41	44	47	50	54
	Dir.	75 78 80	76 79 81	77 80 82	78 81 83	80 83 85	82 84 86	83 85 86	85 87 88	88 90 91
3.50	Ind.	.22	.23	.24	.25	.26	.27	.28	.30	.31
	Hor.	35	37	39	42	44	46	49	52	56
	Dir.	77 80 82	78 81 83	80 82 84	81 83 85	83 85 86	84 86 87	85 87 88	87 89 90	90 91 92
4.00	Ind.	.24	.25	.26	.27	.28	.29	.30	.31	.32
	Hor.	38	39	41	44	46	48	51	54	57
	Dir.	79 82 84	81 83 85	82 84 86	83 85 86	85 87 88	86 88 89	87 89 90	89 90 91	91 92 93
5.00	Ind.	.25	.26	.27	.28	.29	.30	.31	.32	.33
	Hor.	41	42	44	46	48	50	53	55	58
	Dir.	83 85 86	83 85 86	84 86 87	85 87 88	87 89 90	89 90 91	90 91 92	91 92 93	92 93 94

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 50%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.06	.07	.08	.08	.09	.10	.12	.15	.19
	Hor.	06	07	08	09	12	15	19	23	29
	Dir.	19 24 29	21 26 31	24 28 32	27 31 35	30 34 38	34 37 40	38 41 44	44 47 50	51 53 55
0.60	Ind.	.08	.09	.10	.11	.12	.13	.15	.18	.22
	Hor.	09	10	11	13	16	19	23	27	33
	Dir.	28 33 38	30 35 40	33 37 41	36 40 44	39 43 47	43 46 49	47 50 53	52 55 58	59 61 63
0.70	Ind.	.10	.11	.12	.13	.14	.15	.17	.20	.23
	Hor.	11	12	14	16	19	22	26	30	36
	Dir.	35 40 45	37 42 47	40 44 48	43 47 51	46 50 54	50 53 56	54 57 60	59 62 65	65 67 69
0.80	Ind.	.11	.12	.13	.14	.15	.17	.19	.22	.25
	Hor.	13	14	16	18	21	24	28	32	38
	Dir.	41 46 51	42 47 52	45 49 53	47 51 55	50 54 58	54 57 60	57 60 63	62 65 68	68 70 72
0.90	Ind.	.12	.13	.14	.15	.16	.18	.20	.23	.26
	Hor.	15	16	18	20	23	26	30	34	40
	Dir.	45 50 55	46 51 56	49 53 57	51 55 59	53 57 61	57 60 63	60 63 66	64 67 70	70 72 74
1.00	Ind.	.13	.14	.15	.16	.17	.19	.21	.24	.27
	Hor.	16	18	20	22	25	28	32	36	42
	Dir.	48 53 58	49 54 59	52 56 60	54 58 62	56 60 64	59 62 65	62 65 68	66 69 72	72 74 76
1.10	Ind.	.14	.15	.16	.17	.19	.21	.23	.25	.28
	Hor.	17	19	21	23	26	29	33	37	43
	Dir.	50 55 60	51 56 61	54 58 62	56 60 64	58 62 66	61 64 67	64 67 70	68 71 74	74 76 78
1.25	Ind.	.16	.17	.18	.19	.21	.23	.25	.27	.30
	Hor.	19	21	23	25	28	31	35	39	45
	Dir.	53 58 63	54 59 64	57 61 65	59 63 67	61 65 69	64 67 70	67 70 73	70 73 76	76 78 80
1.50	Ind.	.18	.19	.20	.21	.23	.25	.27	.29	.32
	Hor.	22	24	26	29	32	35	39	43	48
	Dir.	57 62 67	58 63 67	61 65 69	62 66 70	64 68 71	67 70 73	70 73 76	73 76 79	79 81 83
1.75	Ind.	.19	.20	.21	.22	.24	.26	.28	.30	.33
	Hor.	25	27	29	32	35	38	42	46	51
	Dir.	61 66 70	62 67 71	65 69 72	66 70 73	68 72 75	71 74 77	73 76 78	76 79 81	81 83 85
2.00	Ind.	.21	.22	.23	.24	.26	.28	.30	.32	.34
	Hor.	27	29	31	34	37	40	44	48	53
	Dir.	64 69 73	65 70 73	68 72 75	69 73 76	71 75 78	74 77 79	76 79 81	79 82 84	83 85 87
2.25	Ind.	.23	.24	.25	.26	.27	.29	.31	.33	.35
	Hor.	29	31	33	36	39	42	46	50	55
	Dir.	67 72 75	68 73 76	71 75 78	72 76 79	75 78 80	77 80 82	79 82 84	82 84 86	85 87 89
2.50	Ind.	.24	.25	.26	.27	.28	.30	.32	.34	.36
	Hor.	31	33	35	38	41	44	48	52	57
	Dir.	71 75 78	72 76 79	74 78 80	76 79 81	78 81 83	79 82 84	82 84 86	84 86 88	87 89 90
3.00	Ind.	.26	.27	.28	.29	.30	.32	.34	.36	.38
	Hor.	34	36	38	41	44	47	51	55	59
	Dir.	75 78 80	76 79 81	77 80 82	78 81 83	80 83 85	82 84 86	84 86 87	86 88 89	89 91 92
3.50	Ind.	.28	.29	.30	.31	.32	.34	.36	.38	.40
	Hor.	37	39	41	44	47	50	54	57	61
	Dir.	77 80 82	78 81 83	80 82 84	81 83 85	83 85 86	84 86 87	86 88 89	88 99 91	91 93 94
4.00	Ind.	.30	.31	.32	.33	.34	.35	.37	.39	.41
	Hor.	40	42	44	46	49	52	56	59	63
	Dir.	79 82 84	81 83 85	82 84 86	83 85 86	85 87 88	86 88 89	88 90 91	91 92 93	93 94 95
5.00	Ind.	.32	.33	.34	.35	.36	.38	.39	.40	.42
	Hor.	43	45	47	49	52	55	58	61	65
	Dir.	83 85 86	83 85 86	84 86 87	85 87 88	87 89 90	89 90 91	91 92 93	92 93 94	94 95 96

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 60%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.07	.08	.09	.10	.11	.12	.15	.18	.22
	Hor.	06	07	08	10	13	16	20	25	31
	Dir.	19 24 29	21 26 31	24 28 32	27 31 35	30 34 38	35 38 41	39 42 45	44 47 50	51 53 55
0.60	Ind.	.10	.11	.12	.13	.14	.16	.19	.22	.26
	Hor.	09	10	12	14	17	20	24	29	35
	Dir.	28 33 38	30 35 40	33 37 41	36 40 44	39 43 47	44 47 50	48 51 54	53 56 59	60 62 64
0.70	Ind.	.12	.13	.14	.15	.16	.18	.21	.24	.28
	Hor.	12	13	15	17	20	23	28	33	39
	Dir.	35 40 45	37 42 47	40 44 48	43 47 51	46 50 54	50 53 56	54 57 60	59 62 65	66 68 70
0.80	Ind.	.13	.14	.15	.16	.18	.20	.23	.26	.30
	Hor.	14	15	17	19	22	25	30	35	41
	Dir.	41 46 51	43 48 53	46 50 54	48 52 56	51 55 59	55 58 61	58 61 64	63 66 69	69 71 73
0.90	Ind.	.15	.16	.17	.18	.20	.22	.25	.28	.32
	Hor.	16	17	19	21	24	27	32	37	43
	Dir.	45 50 55	46 51 56	49 53 57	51 55 59	54 58 62	58 61 64	61 64 67	65 68 71	71 73 75
1.00	Ind.	.16	.17	.18	.19	.21	.23	.26	.29	.33
	Hor.	18	19	21	23	26	29	34	39	45
	Dir.	48 53 58	49 54 59	52 56 60	54 58 62	56 60 64	60 63 66	63 66 69	67 70 73	73 75 77
1.10	Ind.	.17	.18	.19	.21	.23	.25	.27	.30	.34
	Hor.	19	21	23	25	28	31	36	41	47
	Dir.	50 55 60	51 56 61	54 58 62	56 60 64	58 62 66	62 65 68	65 68 71	69 72 75	75 77 79
1.25	Ind.	.19	.20	.21	.23	.25	.27	.29	.32	.36
	Hor.	21	23	25	27	30	33	38	43	49
	Dir.	53 58 63	54 59 64	57 61 65	59 63 67	61 65 69	64 67 70	67 70 73	71 74 77	77 79 81
1.50	Ind.	.21	.22	.23	.25	.27	.29	.31	.34	.38
	Hor.	24	26	28	31	34	37	42	47	52
	Dir.	57 62 67	58 63 67	61 65 69	63 67 71	65 69 72	68 71 74	71 74 77	74 77 80	80 82 84
1.75	Ind.	.23	.24	.25	.27	.29	.31	.33	.36	.39
	Hor.	27	29	31	34	37	40	45	50	55
	Dir.	61 66 70	62 67 71	65 69 72	67 71 74	69 73 76	72 75 77	74 77 79	77 80 82	82 84 86
2.00	Ind.	.25	.26	.27	.29	.31	.33	.35	.38	.41
	Hor.	29	31	33	36	39	42	47	52	57
	Dir.	64 69 73	65 70 73	68 72 75	70 74 77	72 76 79	75 78 80	77 80 82	80 83 85	84 86 88
2.25	Ind.	.27	.28	.29	.31	.33	.35	.37	.39	.42
	Hor.	31	33	35	38	41	44	49	54	59
	Dir.	67 72 75	68 73 76	71 75 78	73 77 80	76 79 81	78 81 83	80 83 85	83 85 87	86 88 90
2.50	Ind.	.29	.30	.31	.33	.35	.37	.39	.41	.44
	Hor.	33	35	37	40	43	46	51	56	61
	Dir.	71 75 78	72 76 79	74 78 80	77 80 82	79 82 84	80 83 85	83 85 87	85 87 89	88 90 91
3.00	Ind.	.32	.33	.34	.35	.37	.39	.41	.43	.46
	Hor.	37	39	41	44	47	50	55	59	63
	Dir.	75 78 80	76 79 81	77 80 82	79 82 84	81 84 86	82 85 87	85 87 88	87 89 90	90 92 93
3.50	Ind.	.34	.35	.36	.37	.39	.41	.43	.45	.47
	Hor.	40	42	44	47	50	53	57	61	65
	Dir.	78 81 83	78 81 83	80 82 84	82 84 86	84 86 87	85 87 88	87 89 90	89 91 92	92 94 95
4.00	Ind.	.36	.37	.38	.39	.41	.43	.44	.46	.48
	Hor.	43	45	47	50	53	56	59	63	67
	Dir.	80 83 85	81 83 85	82 84 86	84 86 87	86 88 89	87 89 90	90 91 92	92 93 94	94 95 96
5.00	Ind.	.38	.39	.40	.41	.43	.45	.46	.48	.49
	Hor.	46	48	50	53	56	59	62	65	69
	Dir.	[illegible]	[illegible]	[illegible] 87 89	86 88 [illegible]	88 90 91	90 91 [illegible]	92 93 94	93 94 95	95 96 97

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 70%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		COEFFICIENTS OF UTILIZATION								
0.50	Ind.	.08	.09	.10	.11	.13	.15	.18	.22	.27
	Hor.	07	08	09	11	14	17	21	27	33
	Dir.	19 24 29	21 26 31	24 28 32	27 31 35	30 34 38	35 38 41	39 42 45	44 47 50	52 54 56
0.60	Ind.	.12	.13	.14	.15	.17	.19	.22	.26	.31
	Hor.	10	11	13	15	18	21	25	31	37
	Dir.	28 33 38	30 35 40	33 37 41	36 40 44	39 43 47	44 47 50	48 51 54	53 56 59	60 62 64
0.70	Ind.	.14	.15	.16	.17	.19	.21	.24	.28	.33
	Hor.	13	14	16	18	21	25	29	35	41
	Dir.	35 40 45	37 42 47	40 44 48	43 47 51	46 50 54	50 53 56	54 57 60	59 62 65	66 68 70
0.80	Ind.	.16	.17	.18	.19	.21	.23	.26	.30	.35
	Hor.	15	16	18	20	23	27	32	38	44
	Dir.	41 46 51	43 48 53	46 50 54	48 52 56	51 55 59	55 58 61	59 62 65	63 66 69	70 72 74
0.90	Ind.	.17	.18	.19	.21	.23	.25	.28	.32	.37
	Hor.	17	18	20	22	25	29	34	40	46
	Dir.	45 50 55	47 52 57	50 54 58	52 56 60	54 58 62	58 61 64	61 64 67	65 68 71	72 74 76
1.00	Ind.	.19	.20	.21	.23	.25	.27	.30	.34	.38
	Hor.	18	20	22	24	27	31	36	42	48
	Dir.	48 53 58	49 54 59	52 56 60	54 58 62	56 60 64	60 63 66	63 66 69	67 70 73	74 76 78
1.10	Ind.	.20	.21	.23	.25	.27	.29	.32	.35	.39
	Hor.	20	22	24	26	29	33	38	44	50
	Dir.	50 55 60	51 56 61	54 58 62	56 60 64	58 62 66	62 65 68	65 68 71	69 72 75	76 78 80
1.25	Ind.	.22	.23	.25	.27	.29	.31	.34	.37	.41
	Hor.	22	24	26	29	32	36	41	47	53
	Dir.	53 58 63	54 59 64	57 61 65	59 63 67	61 65 69	65 68 71	68 71 74	72 75 78	78 80 82
1.50	Ind.	.25	.26	.28	.30	.32	.34	.37	.40	.44
	Hor.	25	27	30	33	36	40	45	50	56
	Dir.	57 62 67	58 63 67	61 65 69	63 67 71	65 69 72	69 72 75	72 75 78	75 78 81	81 83 85
1.75	Ind.	.27	.28	.30	.32	.34	.36	.39	.42	.46
	Hor.	28	30	33	36	39	43	48	53	59
	Dir.	61 66 70	62 67 71	65 69 72	67 71 74	69 73 76	72 75 78	75 78 80	78 81 83	83 85 87
2.00	Ind.	.30	.31	.32	.34	.36	.38	.41	.44	.48
	Hor.	31	33	36	39	42	46	51	56	61
	Dir.	64 69 73	65 70 73	68 72 75	70 74 77	72 76 79	75 78 80	78 81 83	81 84 86	85 87 89
2.25	Ind.	.32	.33	.34	.36	.38	.40	.43	.46	.50
	Hor.	33	35	38	41	44	48	53	58	63
	Dir.	67 72 75	68 73 76	71 75 78	73 77 80	76 79 81	78 81 83	81 84 86	84 86 88	87 89 91
2.50	Ind.	.34	.35	.36	.38	.40	.42	.45	.48	.51
	Hor.	35	37	40	43	46	50	55	60	65
	Dir.	71 75 78	72 76 79	74 78 80	77 80 82	79 82 84	81 84 86	84 86 88	86 88 90	89 91 92
3.00	Ind.	.37	.38	.39	.41	.43	.45	.47	.50	.53
	Hor.	39	41	44	47	50	54	58	63	68
	Dir.	75 78 80	76 79 81	78 81 83	80 83 85	82 85 87	84 86 88	86 88 89	88 90 91	91 93 94
3.50	Ind.	.40	.41	.42	.44	.46	.48	.50	.52	.55
	Hor.	42	44	47	50	53	57	61	66	71
	Dir.	78 81 83	79 82 84	81 83 85	83 85 87	85 87 88	86 88 89	88 90 91	90 92 93	93 95 96
4.00	Ind.	.42	.43	.44	.46	.48	.50	.52	.54	.56
	Hor.	45	47	50	53	56	60	64	68	73
	Dir.	80 83 85	82 84 86	83 85 87	85 87 88	87 89 90	88 90 91	90 92 93	93 94 95	95 96 97
5.00	Ind.	.45	.46	.47	.48	.50	.52	.54	.56	.58
	Hor.	49	51	54	57	60	63	66	70	75
	Dir.	84 86 87	84 86 87	85 87 88	87 89 90	89 91 92	91 92 93	93 94 95	94 95 96	96 97 98

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Reflection Factors

The proportions of light reflected by walls and ceilings of various colors, that is, their Reflection Factors, have an important bearing on both the natural and the artificial lighting. The proportion reflected will depend somewhat upon the color of the incident light. The figures here given show what proportion of the light of MAZDA lamps these painted surfaces reflect. Reflection Factors are of

No. 1
White Paper
81%

No. 2
Gray
73%

No. 3
Gray
67%

No. 4
Gray
51%

No. 5
Gray
46%

No. 6
French Gray
39%

No. 7
Gray
28%

No. 8
Gray
18%

No. 9
Ivory White
76%

No. 10
Caen Stone
72%

No. 11
Ivory
72%

No. 12
Ivory Tan
58%

No. 13
Primrose
67%

No. 14
Lichen Gray
70%

No. 15
Pearl Gray
70%

No. 16
Silver Gray and Caen Stone
50%

# of Colored Surfaces

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special usefulness in determining the Coefficient of Utilization (ratio of light delivered at the work to total light of lamps) applicable to an interior. The Reflection Factor of any colored surface can be approximated by comparing it with these samples.

No. 17
Buff Stone and Pale Azure
44%

No. 25
Forest Green
21%

No. 18
Buff
59%

No. 26
Olive Green
14%

No. 19
Buff Stone
51%

No. 27
Pale Azure and White
53%

No. 20
Tan
37%

No. 28
Pale Azure
36%

No. 21
Cocoanut Brown
22%

No. 29
Sky Blue
31%

No. 22
Satin Green
67%

No. 30
Shell Pink
57%

No. 23
Bright Sage and Ivory Tan
47%

No. 31
Pink
51%

No. 24
Bright Sage
43%

No. 32
Cardinal Red
27%

TABLE V.—(*Continued.*)

Ceiling Reflection Factor 80%

Wall Reflection Factor		0%	10%	20%	30%	40%	50%	60%	70%	80%
Room Ratio		**COEFFICIENTS OF UTILIZATION**								
0.50	Ind.	.09	.10	.11	.12	.14	.17	.21	.25	.31
	Hor.	07	08	09	11	14	18	22	28	35
	Dir.	19 24 29	21 26 31	24 28 32	27 31 35	30 34 38	35 38 41	39 42 45	44 47 50	52 54 56
0.60	Ind.	.13	.14	.15	.16	.18	.21	.25	.29	.35
	Hor.	10	12	14	16	18	22	27	33	40
	Dir.	28 33 38	30 35 40	33 37 41	36 40 44	39 43 47	44 47 50	48 51 54	53 56 59	61 63 65
0.70	Ind.	.16	.17	.18	.19	.21	.24	.28	.32	.38
	Hor.	13	15	17	19	22	26	31	37	44
	Dir.	35 40 45	37 42 47	40 44 48	43 47 51	46 50 54	50 53 56	54 57 60	59 62 65	67 69 71
0.80	Ind.	.18	.19	.20	.22	.24	.27	.30	.34	.40
	Hor.	15	17	19	22	25	29	34	40	47
	Dir.	41 46 51	43 48 53	46 50 54	48 52 56	51 55 59	55 58 61	59 62 65	64 67 70	71 73 75
0.90	Ind.	.20	.21	.22	.24	.26	.29	.32	.36	.42
	Hor.	17	19	21	24	27	31	36	42	49
	Dir.	46 51 56	47 52 57	50 54 58	52 56 60	55 59 63	59 62 65	62 65 68	66 69 72	73 75 77
1.00	Ind.	.22	.23	.24	.26	.28	.31	.34	.38	.44
	Hor.	19	21	23	26	29	33	38	44	51
	Dir.	49 54 59	50 55 60	53 57 61	55 59 63	57 61 65	61 64 67	64 67 70	68 71 74	75 77 79
1.10	Ind.	.23	.24	.26	.28	.30	.33	.36	.40	.45
	Hor.	21	23	25	28	31	35	40	46	53
	Dir.	51 56 61	52 57 62	55 59 63	57 61 65	59 63 67	63 66 69	66 69 72	70 73 76	77 79 81
1.25	Ind.	.25	.26	.28	.30	.33	.36	.39	.43	.47
	Hor.	23	25	28	31	34	38	43	49	56
	Dir.	54 59 64	55 60 65	58 62 66	60 64 68	62 66 70	66 69 72	69 72 75	73 76 79	80 82 84
1.50	Ind.	.28	.29	.31	.33	.36	.39	.42	.46	.50
	Hor.	26	29	32	35	38	42	47	53	59
	Dir.	58 63 68	59 64 68	62 66 70	64 68 72	66 70 73	70 73 76	72 75 78	76 79 82	83 85 87
1.75	Ind.	.31	.32	.34	.36	.39	.42	.45	.48	.52
	Hor.	29	32	35	38	42	46	51	56	62
	Dir.	62 67 71	63 68 72	66 70 73	68 72 75	70 74 77	73 76 79	75 78 80	79 82 84	85 87 89
2.00	Ind.	.34	.35	.37	.39	.42	.45	.48	.51	.54
	Hor.	32	35	38	41	45	49	54	59	65
	Dir.	65 70 74	66 71 74	69 73 76	71 75 78	73 77 80	76 79 81	78 81 83	82 85 87	87 89 91
2.25	Ind.	.36	.37	.39	.41	.44	.47	.50	.53	.56
	Hor.	34	37	40	44	48	52	57	62	67
	Dir.	68 73 76	69 74 77	72 76 79	74 78 81	77 80 82	79 82 84	81 84 86	85 87 89	89 91 93
2.50	Ind.	.38	.39	.41	.43	.46	.49	.52	.55	.58
	Hor.	36	39	42	46	50	54	59	64	69
	Dir.	71 75 78	72 76 79	74 78 80	77 80 82	79 82 84	81 84 86	84 86 88	87 89 91	90 92 94
3.00	Ind.	.42	.43	.45	.47	.49	.52	.55	.58	.61
	Hor.	40	43	46	50	54	58	62	67	72
	Dir.	75 78 80	76 79 81	78 81 83	80 83 85	82 85 87	84 87 89	87 89 90	89 91 92	92 94 95
3.50	Ind.	.45	.46	.48	.50	.52	.54	.57	.60	.63
	Hor.	44	47	50	54	58	62	66	70	74
	Dir.	78 81 83	79 82 84	81 83 85	83 85 87	85 87 88	87 89 90	89 91 92	91 93 94	94 96 97
4.00	Ind.	.48	.49	.51	.53	.55	.57	.59	.61	.64
	Hor.	47	50	53	57	61	64	68	72	76
	Dir.	80 83 85	82 84 86	83 85 87	85 87 88	87 89 90	89 91 92	91 93 94	94 95 96	96 97 98
5.00	Ind.	.51	.52	.54	.56	.58	.60	.62	.64	.66
	Hor.	51	54	57	60	64	67	71	74	78
	Dir.	84 86 87	85 87 88	86 88 89	87 89 90	89 91 92	92 93 94	94 95 96	95 96 97	97 98 99

NOTE:—Discussion is combined with that for Walls and Floors, page 131.

WALLS AND FLOORS—THEIR EFFECTS ON LIGHTING.*

BY VAN RENSSELAER LANSINGH.

Synopsis: This paper gives the utilization factors of several different units of the direct, semi-indirect and totally indirect types designed for the gas-filled lamp when tested under varying conditions of walls and floor. It also analyzes the effects of variable wall and floor coverings and shows their interaction.

In the Spring of this year, the writer had occasion to make a number of tests in connection with the Electrical Testing Laboratories, on different types of illuminants to determine the intensity of illumination and the coefficients of utilization with different floor and wall coverings. As the results of these tests, showing as they do the effect of variable walls and floors with direct, indirect and semi-indirect lighting, should be of considerable interest to the lighting profession, they are given here.

The room in which the tests were made was approximately 12 ft. x 14 ft. with ceiling height 10 ft. 3 in. The east and west walls were divided into three panels each; the north and south walls were each divided into two panels and mirrored doors. The ceiling and trim were of ivory white finish and the walls of yellowish tan color corded material, the cords running horizontally. The walls could be changed by covering the panels with heavy brown or green window shades, a white semi-glossed paper, and also a grey mat paper.

REFLECTION FACTOR OF TRIM, CEILING, FLOOR AND WALL COVERINGS.

		Per cent. reflection factor.
Trim	Ivory white	47
Floors	Average of dark and light cork squares	17
	White paper	55
	Black cloth	2
Walls	Sand color	31
	Brown shades	11
	Green shades	11
	Grey mat paper	22
	White paper	55
Ceiling	Cream white	52

* Paper prepared for Presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

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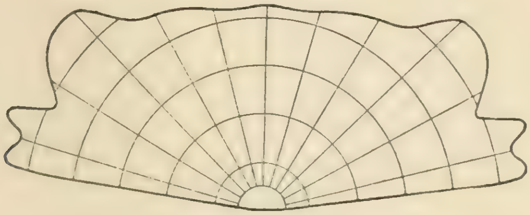
Test room

The floor was made of 8-in. blocks of light and dark grey cork composition. In addition to the regular flooring a black cotton flannel cloth, cotton side up, and a semi-glossed white paper were used. The reflection factors are given in the preceding table:

UNITS TESTED.

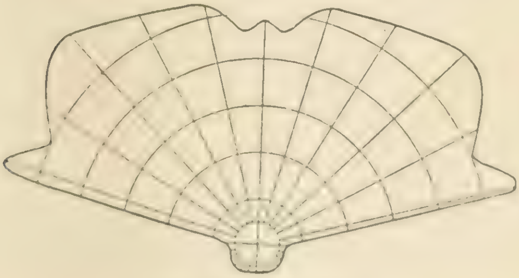
Three types of units were tested—totally indirect, semi-indirect and direct.

Unit No. 1: Totally indirect. Made of corrugated mirrored glass surrounded by a metal bowl.



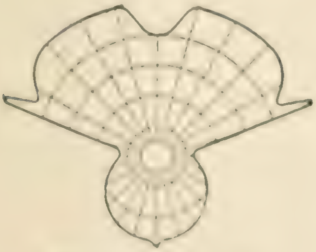
Photometric curve.

Unit No. 2: Semi-indirect. A deep bowl made of dense opal glass giving high reflection and low transmission



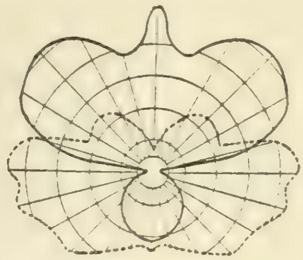
Photometric curve.

Unit No. 3: Semi-indirect. A thin mottled opal glass hemisphere with good diffusion and low absorption.



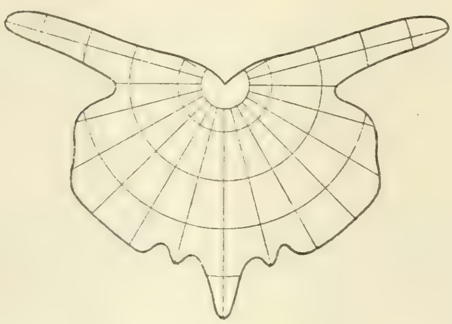
Photometric curve.

Unit No. 4: Semi-indirect. White enameled steel reflector to throw light to the ceiling with opal diffusing plate covering opening at bottom.



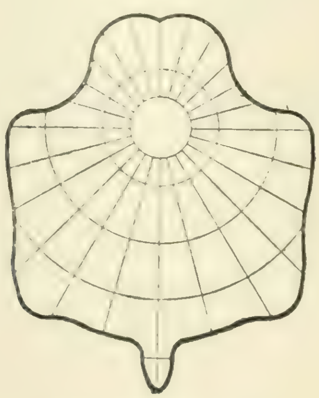
Photometric curve of unit and bare 150-watt lamp used in all tests.

Unit No. 5: Direct. Deep opal bowl with flat white diffusing plate above.



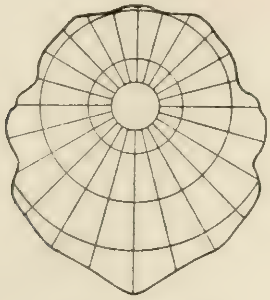
Photometric curve.

Unit No. 6: Direct. One piece glass unit, top part being an enameled reflector, bottom diffusing enameled bowl connected by clear glass.



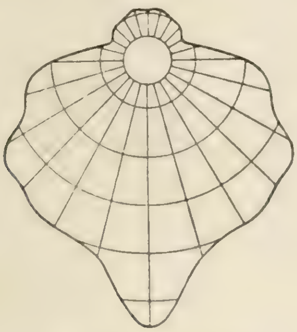
Photometric curve.

Unit No. 7: Direct. Unit similar to No. 6 but manufactured by a different company.



Photometric curve.

Unit No. 8: Direct. Diffusing bowl supported by a clear glass neck and covered by opal glass reflector.



Photometric curve.

The following table gives the total output as well as the flux in both the upper and lower hemispheres.

PHOTOMETRIC RESULTS.

Character of unit.	Indirect	Semi-indirect.			Direct			
Unit No.	1	2	3	4	5	6	7	8
Per cent. flux above horizontal	70.9	67.2	60.0	56.6	26.4	27.5	34.2	16.3
Per cent. flux below horizontal	.4	9.1	20.6	15.2	52.7	47.6	45.8	50.0
Per cent. total flux or output	71.3	76.3	80.6	71.8	79.1	75.1	80.0	66.3

The tests showed the utilization factors given in the table on the following page.

UTILIZATION FACTORS OF DIFFERENT UNITS WITH VARIABLE WALLS.

Ceiling coefficient of reflection 52 per cent. Floor coefficient of reflection 17 per cent.

Character of unit.	Indirect.		Semi-indirect.					Direct.							
Unit No.	1	1	2	3	3	4	4	5	5	6	6	7	7	8	8
Per cent. reflecting value of walls	11	31	31	11	31	11	31	11	31	11	31	11	31	11	31
Average footcandles—30-inch horizontal plane	1.86	2.09	2.75	4.18	4.36	3.53	3.82	3.31	3.77	3.46	3.66	3.48	3.75	2.90	3.33
Lumens—30-inch plane	307	345	454	690	720	583	630	546	620	571	604	574	619	479	550
Per cent. coefficient of utilization of lamp	15	17	22	34	35	28	31	27	30	28	29	28	30	23	27

EFFECT OF VARIABLE WALLS AND FLOOR WITH SEMI-INDIRECT UNIT NO. 4.

Ceiling coefficient of reflection 52 per cent.

TABLE A—CONSTANT WALLS; VARIABLE FLOORS.

Per cent. reflecting value of walls	11	11	11	22	31	31	31	55	55	55
Per cent. reflecting value of floor	2	17	55	2	2	17	55	2	17	55
Average footcandles 30-inch horizontal plane	3.18	3.53	3.64	3.48	3.38	3.82	3.93	4.04	4.28	4.67
Lumens—30-inch plane	525	583	600	575	558	630	649	666	707	770
Per cent. coefficient of utilization of lamps	26	28	29	28	27	31	32	32	34	37

TABLE B—CONSTANT FLOORS; VARIABLE WALLS.

Per cent. reflecting value of floors	2	2	2	2	17	17	17	55	55	55
Per cent. reflecting value of walls	11	22	31	55	11	31	55	11	31	55
Lumens—30-inch plane	525	575	558	666	583	630	707	600	649	770
Per cent. coefficient of utilization of lamp	26	28	27	32	28	31	34	29	32	37

From this table we see that the effect of varying the color of the walls from 11 per cent. to 31 per cent. had but comparatively little effect on the horizontal plane of illumination. The difference to the eye in the apparent brightness of the room, when the walls were covered with dark brown or green curtains (11 per cent. reflecting value) and the natural yellowish walls (31 per cent. reflecting value) was much greater than the difference of horizontal illumination intensity. This was true of all three types of units.

As would be expected, units 1 and 2 which depend almost entirely on the ceiling for reflecting light to the horizontal working plane, give a much lower efficiency than the direct units or the semi-indirect units with a large direct component. On the other hand, direct lighting units so constructed as to entirely shield the lamp and diffuse its light, have no higher efficiency than semi-indirect units with large direct components.

Semi-indirect unit No. 4 was tested with both variable walls and floors and the results are given in the two tables on the preceding page.

From these tests we may draw the following conclusions:

Effect of Floors: We can increase the illumination on the working plane by about 15 per cent. if the floors are increased in reflecting value from 2 per cent. to 55 per cent., if the walls of the room are kept constant in reflecting value. This is true whether the walls have a high reflecting value (55 per cent.) or a low value (11 per cent.).

Effect of Walls: We can increase the illumination on the working plane by about 25 per cent. if the reflecting value of the walls are raised from 11 per cent. to 55 per cent., irrespective of the reflecting power of the floors, provided this is constant. In other words, we can still get this increase whether the floor has a low reflecting value, namely 2 per cent. or a high reflecting value, 55 per cent.

Interaction of Walls and Floors: With both walls and floor having a reflecting value of 55 per cent., we find an increase in illumination on the working plane of about 50 per cent. over what we get when the walls have a value of 11 per cent. and the floor 2 per cent. This shows that with this type of unit the interplay of walls and floor is important.

If the walls are removed, as is the case in large offices, we can expect a reduction in illumination of from 10 per cent. to 20 per cent., depending on the reflecting value of the walls, which however would be more than offset by the added illumination from adjoining units.

CONCLUSIONS.

1.—With units built for gas-filled lamps to diffuse the light and redirect it to the working plane, we find that direct units and semi-indirect with a large direct component, have about the same efficiency, the utilization factor being about 30 per cent.

2.—With totally indirect units and semi-indirect with a small direct component, we find a much lower efficiency, the utilization factor varying from 15 per cent. to 22 per cent.

3.—The effect of the floor, while much less than the walls, is not inconsiderable and may in extreme cases add 15 per cent. to the illumination.

4.—The effect of the walls alone is much less than is often supposed, the extreme difference not exceeding 25 per cent.

5.—The interaction of walls and floors is often considerable, being 50 per cent. in extreme cases.

6.—A good idea of the performance to be expected under ordinary working conditions for different units can be obtained by taking the values corresponding to walls 31 per cent. and floor 17 per cent.

DISCUSSION.

Mr. Little: The mounting heights of the various units are as follows:

No.	1	39	inches	from	the	ceiling.
No.	2	37	"	"	"	"
No.	3	37	"	"	"	"
No.	6	13½	"	"	"	"
No.	5	7	"	"	"	"
No.	4	39	"	"	"	"
No.	7	15	"	"	"	"
No.	8	10	"	"	"	"

Note:—Discussion is combined with that for Coefficients of Utilization.

MR. TAYLOR (Washington, D. C.): These two papers appear to me to be very valuable contributions to the profession of illuminating engineering. They tend to remove some of the factors from the realm of guesswork, and put them on an engineering basis.

Mr. Anderson spoke of the necessity for the determination of reflection factors, and emphasized the necessity for that determination being accurate. There are a number of methods in use for the determination of reflection factors, but, so far as I know, there is no very convenient method, none that can be utilized anywhere except in the laboratory. Some of these methods depend on a definite value assigned to a particular surface, the test surfaces being compared with the standard surface in some manner. The values for certain surfaces have been given in previous papers before this Society. If I remember correctly the value given for magnesium carbonate, the surface most often used, is eighty-eight per cent. Now it is my opinion that that value is very considerably wrong, and I think I have fairly definite proof of it. I presented a paper here a few years ago on the integrating sphere and in that paper I showed by tests in the sphere that we had a reflection factor of about ninety-two per cent. That was checked by other measurements and I don't believe that that surface is as white as magnesium carbonate. (Measurements which I have made since the Convention show the reflection factor of magnesium carbonate to be about ninety-six per cent.) Some time ago I was working on a paper on the theory of the sphere and it was convenient for me to work out at that time the theory of an instrument which I had had in mind, that is, a reflectometer for measuring reflecting powers. The instrument is just a small sphere with a diffusing white surface and a piece cut off of it. The most convenient form I think is to cut off an amount of the surface such that the remaining portion is ninety per cent. of the whole sphere.

This has a milk glass window in the side opposite the large hole, and about ninety degrees from the window is a small opening thru which light from a small lamp is projected onto the opposite wall of the sphere. The instrument can be used as a portable reflectometer, and measurements of reflection factors can be made anywhere, without removing the test surfaces. The

instrument is different from a number of those in use as it is what I think you might call an absolute instrument, if I understand the meaning of that term correctly, in that it does not require a standard surface for calibration. The only thing required is a surface having the same reflecting power as the walls of the sphere. The theory of this instrument is rather complicated, and I have not had any chance to check it up until lately, altho I have had one of the instruments constructed for about two years, but I did check it up a short time ago and apparently proved that the theory is correct.

I believe that this instrument will contribute quite a bit to the ease of making such measurements when finally perfected. An exposition of the theory of the instrument will probably be published in about two or three months.

Mr. Stair: I wish to call attention to the conclusions of Mr. Lansingh's paper, especially paragraph No. 2, where it reads, "With totally indirect units and semi-indirect, with a small direct component, we find a much lower efficiency, the utilization factor varying from 15 per cent. to 22 per cent."

The conditions under which the tests were made, especially as regards the arrangement of the equipment are not sufficiently described in the paper to enable one to analyze the results so as to account for the efficiencies obtained.

The results in efficiency as given in the general conclusions, 15 to 22 per cent. for commercial indirect lighting installations, do not conform to results that are met with in practice, furthermore, they do not conform to results of tests that have been made by Mr. Harrison and others.

Mr. Macbeth: I wish to ask, first, if the brightness measurements referred to by Mr. Lansingh are available for the walls and ceilings? It is easily possible to bring about high illumination intensities on a horizontal plain with unsatisfactory side wall conditions, that is, the side wall being largely in the range of vision. How were the coefficients determined? Is it sufficient to say that the coefficients are such factors as you would use, if the ordinary wall and ceiling work were considered?

WARD HARRISON: In reading these two papers and comparing some of the figures of Mr. Lansingh's paper with our own computations I notice a very considerable discrepancy both in the coefficient of utilization values obtained and in their relative order for the various characteristic distribution curves. This situation is largely explainable considering that our tests were based on arrangement of lighting units which provided fairly uniform illumination. Where uniform illumination is desired it is of course necessary to place lamps near the side walls to bring up the illumination at the sides of the room, with the natural result that more of the light falls on the side walls and their color becomes relatively more important in determining the percentage of useful light. In making a study of the efficiency of units to be used in industrial or office work rooms, it would appear that only installations giving reasonably uniform illumination should be compared. For in work rooms it is really the minimum intensity that is of importance rather than the average of several values at different points which might be widely dissimilar. On the other hand, in some rooms of the home, for instance, where non-uniform illumination might be quite desirable, it does not seem that a utilization factor is of any particular value to the designer.

In examining the curves and noting the hanging heights of some of the units in the room tests described in Mr. Lansingh's paper, it is evident that there must be a great difference between the illumination intensity near the wall and directly under the fixture. It would seem that in some of the lighting systems tested this difference might easily be in the ratio of 5 to 1. On the other hand, with the totally indirect fixture, for example, the ratio of maximum to minimum illumination might be very much less, perhaps only 2 to 1, so that a comparison on the basis of minimum illumination would be more favorable to the indirect than the coefficients found by Mr. Lansingh would indicate. I wonder if Mr. Little happens to have with him the foot-candle values for the various test stations using the different lighting units?

Our test data indicate a wide variation in the effect on the coefficient of utilization of the individual variables, depending on the size of the room and the characteristic distribution curve of the fixture used. For example, in a very small high room the

floor reflection factor is quite unimportant, while the color of the walls might change the illumination by even as much as 100 per cent. In a very large low room, on the other hand, the wall color would have but a small effect on the average illumination; but in this case a light colored floor might be quite an important factor. Again, it is obvious that the effect of a light colored ceiling is very much different as applied to an indirect system, for instance, than to a direct type which depends but little on the ceiling for reflection. Hence, definite statements as to the percentage effect of any one particular variable in an installation must be rather carefully limited to the specific conditions existing in that installation. For example, if, in Mr. Lansingh's tests, the ceiling had been of a dark tone, the coefficient of utilization values for some of the units would have been greatly reduced, while with the more direct types the results would have been affected to a much less extent.

Mr. Powell: From a casual reading of Mr. Lansingh's paper it would seem that the tests on lighting effects of the walls and floors were carried out in a very small room. The conclusions which are drawn seem open to question as applying to general lighting conditions in larger rooms, quoting for example, on Page 131, "If the walls are removed, as is the case in larger offices, we can expect a reduction in illumination of from 10 per cent. to 20 per cent. depending on the reflecting value of the walls which, however, would be more than off-set by the added illumination from adjoining units."

At first reading of this paragraph is would seem to imply that the large room would have considerably less illumination, unless one realized the full import of that last phrase.

As to the low efficiencies of the indirect units, I agree entirely with Mr. Stair that in ordinary practice, except in a very small room, they are entirely too low. The effect of walls and ceilings on the resultant illumination is of equal importance in industrial lighting. On various occasions when interviewing contractors, dealers and others who have to do with the designing of illumination, I have attempted to draw especial attention to the question of the color of the ceilings as affecting illumination and maintenance. In a test conducted by myself in a new building, this

effect was quite apparent. The floors were light maple, the ceiling freshly painted with paint having a high coefficient of reflection, the walls also were light in color. In this test I found a utilization factor of about unity. As this result was questioned I ran a check test and found the original results to be right within the errors of test, and realized that I had a condition due to the multiple reflection of the ceiling, floor and walls approaching an Ulbrich sphere.

This brought out the desirability in the industrial plant, in particular, of keeping surroundings light in color if we want to get maximum illumination for the minimum expenditure of energy.

MR. WILLCOX: I want to express my appreciation to Mr. Harrison and Mr. Anderson for giving us so much information on this subject. I have found in my practice in England that a good deal of educational work is necessary to introduce a new unit, such as the lumen, and to help people understand it. I always thought that that was a past condition here, and that you had accepted and adopted the lumen. I was very much surprised, therefore, in talking with a number of practical men to find the lumen was still considered a kind of "highbrow" term for use only by engineers. He still talks in terms of candlepower. I venture the suggestion that the definition of the word "lumen" and how to use it should be more generally known so that everyone may realize that modern lighting work is to be dealt with on the basis of the amount of flux in lumens taken in connection with the characteristic candlepower distribution for the lighting units employed.

MR. LITTLE: The reflection factor of 88 per cent. for magnesium carbonate was established by Dr. Nutting some years ago, and the laboratories have used it ever since. Mr. Macbeth brings up the question of brightness. The test did include brightness of ceilings and walls, and these values are available from the test data. The variation in illumination with the semi-indirect unit upon which most of the tests were made, was in the neighborhood of four to one with the light walls and floor, and in some cases there was an even greater variation. In the case of the

indirect unit the variation was less than two to one. Mr. Powell asks the size of the room. The dimensions are given in the paper, approximately 12 to 14. It was a very small room and had no windows. However, the complete descriptions are given.

EARL A. ANDERSON: (In reply). Mr. Macbeth inquired as to the method of determination of the reflection factors for the samples in the booklets which were distributed. The reflection factors were not based on a comparison with magnesium carbonate, but instead, were found by a method somewhat similar to that described by Mr. Taylor, using a small box photometer and comparing readings against diffuse standard samples whose reflection factors had been found from a point by point method. Incidentally, the reflection factor values of the samples in the booklets were read independently by another laboratory with the result of a close order of agreement. The need for accurate determination of reflection factors in making comparative coefficient of utilization tests for different types of lighting fixtures is quite obvious.

As to the coefficients of utilization for totally indirect lighting systems, in Table 4-B of the paper, values as high as 42 per cent. will be found for such a system in a large room with light walls and ceiling. In a medium sized room the value is 31 per cent., while in a very small room the result is only 22 per cent. These differences illustrate the great importance attaching to the room proportions, as well as the color of the surfaces, in determining upon the coefficient of utilization to be used in computing an installation.

One speaker mentioned the possibility of a utilization greater than 100 per cent., and in this connection in Table 5 of the paper the values for the direct component with dark floor conditions are found to run as high as 99 per cent. Obviously, applying the correction for a light colored floor, this value might be increased to 120 or 130 per cent. However, even though it is true that if the reflection factor of the ceiling, walls and floor could be made sufficiently high, it would be quite simple to secure utilizations much greater than 100 per cent., nevertheless, in the usual installation, even with efficient accessories, the absorption of the different surfaces reduces the coefficient to values well under 100 per cent.

For example, values of 30 to 40 per cent. in average rooms with the usual lighting equipment are more common than values of 50 to 70 per cent.

The series of tests reported in this paper were designed to show the wide variation in the percentage of useful light, depending upon the type of equipment and the color and proportions of the room, and to reduce these data to tables suitable for use. It was felt that a practical set of tables of this nature would be of distinct advantage in lessening the effort required to determine the purely arithmetical constants of lighting design, with the result that more time could be profitably employed in the solution of the important problems of distribution of light, of glare and of specular reflection.

LIGHTING IN ENGLAND.*

BY FRANCIS W. WILLCOX.

It is a privilege and an honor—a privilege to return after so many years and see so many good friends and be one of you once again—an honor to be asked even to give a short talk to you, because it is not a written paper that I am going to present, but rather a talk about examples of English lighting equipment and installations. I wish to express my praise of and admiration for the excellent work of the Illuminating Engineering Society. I consider it one of the most fruitful, successful engineering societies of the modern day. We are endeavoring to carry on Illuminating Engineering work by precept and practice in Great Britain.

The English Illuminating Engineering Society has progressed, but is still a young body in respect to numbers and influence, and output of papers and work as compared to your Society. In England, the attitude towards commercial interests connected with an Engineering Society, is quite different from that in this country. They do not so freely look to the manufacturer and commercial representatives for ideas and they do not receive them with the interest and co-operation that you give here. They rather feel that too much of that in a society tends to detract from the worth of the society. At least that has been the attitude in the past, but I have hoped that the war would break this attitude down in a measure.

In the United States anything that is good for illuminating engineering work you give approval and accept it on the basis of how good it is, not from whom it comes. Chief among the activities of the English Illuminating Engineering Society, has been the work with the British Government authorities in the matter of legislation for the betterment of industrial lighting.

I regret I did not have the good fortune to hear the discussion this morning on industrial codes as we hope shortly to have in England an industrial code. It will be an industrial code for the whole country as we have one authority there to deal with—the British Home Office—which has already presented reports bear-

* Address before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 2[illegible], 1919, Chicago, Ill. (Proof not read by author.)

ing on the subject. I have here some lantern slides which were brought over first to show my associates in business some of the work we are doing in England. Mr. Stickney thought it would be very helpful and interesting to the Society to see some of this work and asked me if I would not go on the program. (Mr. Willcox then exhibited lantern slides and described them to the meeting.)

I have come to the conclusion myself that the element—uncleanliness in lighting fittings—is one of the greatest difficulties we have to contend with and that an effective method of avoiding light deterioration due to dirt would be to make fittings as far as possible completely enclosed, dust-proof, and if necessary, gas tight. Both here and in England, the lamp manufacturers' pamphlets have talked a great deal about ventilation for lanterns and fittings employing gas-filled lamps. When you come to analyze it, ample radiation on your lantern casings can dissipate practically as well as it can be done by ventilation. If by such means we can employ a completely closed lantern or fitting, we can eliminate to the very fullest degree, dust and dirt, and its consequent deterioration in the light.

Referring to the "rise and fall pendants" as they are called, I think there are types of these pendants that American practice could advisably adopt. The use of lamp cord as a means of supporting and lowering lamps is not objectionable to the underwriters in England, and I do not think should be here. It is certainly a great convenience and advantage to have the lights on a rise and fall arrangement with counterweights, so you can raise or lower them to any position you like.

The English tumbler pattern of wall switch is also a device that is very convenient and very easily manipulated, and I am gratified to see that one of the American manufacturers is putting on the market a type of this switch. The wall switches used in America, are, in many instances too rigid and difficult to operate. Those elements, I think, ought to be more fully taken into consideration in the design of fittings and use of light. Chief among the advantages of electric light are its convenience and perfect adaptability. Our designs of appliances, fittings and methods of use tend too often to make the use of electric light almost too rigid and inflexible, as though it were a flame illuminant.

Much as there may be to do in this country, there is, relative to installations made, a much greater amount of work awaiting the engineer in Great Britain to accomplish, the war of course having hindered the progress of this work. Now the war is over and we are resuming that work in marked earnestness and enthusiasm. I want to say that all of us over there working in this cause derive a great deal of inspiration, information and assistance from the study of your excellent TRANSACTIONS and the work of your Society—of our Society, because I am still a member of it, and I hope that you will steadily carry on this good work and continue to be an inspiration to all those of us in other parts of the world. I thank you.

DISCUSSION.

MR. TILLSON: I was very much interested in the pictures of those industrial units, especially the ones built into the roof. There seems to be a tendency in American practice to consider any factory lighting unit which is not a piece of tin (aluminized or porcelain enameled) too expensive to market. The thinnest gauge steels, 26 or 28 gauge, porcelain enameled, together with the flimsiest fittings, seem to be all that we feel capable of selling, but it looks as if, in English practice, they are willing to build a lighting unit comparable to the ruggedness of the rest of the equipment that goes into a factory. Industrial managers do not seem averse to spending from eight to ten or even twelve thousand dollars for an automatic or semi-automatic machine which will do what they ask of it, but it seems that if the lighting salesman asks more than one or two dollars for an electric fixture, he is demanding something extortionate. We have been experimenting here in Chicago on a self-cleaning unit, something the style of that which was shown here, with a glass cover plate and a squeegee connected with the stem switch so that the unit cannot be lighted or dimmed without being cleaned. But right at the start the objection was raised that the device would cost too much money and nobody would buy it. I do not think that is true. The development of the fixture is not completed yet, so we do not know what its sale will be, but I certainly think the lighting fraternity should not be so timid. We should build a unit that will do the work we know must be done, whether it

costs one dollar or twenty. The wildest fixture price cannot possibly compare with constant loss on factory payrolls, due to improper and inefficient lighting. Everybody knows that a unit above a moulding floor does not stand up more than two or three weeks. Due to the peculiar foundry dirt collection, its efficiency drops forty or fifty per cent. in that interval. Furthermore, the fixtures are mounted so high the foundrymen can't get at them. These British units shown in the pictures at least cut out the collection of dirt and grease from the bulb of the lamp and the interior of the reflector. They cost more money than the American reflectors, but I am mighty glad to see that there is a move elsewhere toward greater ruggedness, and some provisions for the maintenance of the unit after it is once erected.

LIEUT. HIBBEN: I would like to add the thought that it does us all good sometimes to "back away" far enough from an accepted idea to get a good perspective of it. If we can profit by seeing what somebody else does, and not close our eyes to some of these improvements or differences that the author has illustrated, it will benefit us and establish a certain interchange or liason with our friends, by which we may both furnish them and obtain from them some good ideas. I have had the pleasure of seeing lighting fixtures and all sorts of lighting conditions in England and France and other countries recently, and I did so first with the all too prevalent American thought, perhaps, of coming to scoff, and finally, as so many often do, remaining to praise.

Of course there was no especial lighting in England that I observed, because the exposed lamps were painted black or simply didn't exist, but after the armistice I saw in France the development of some interesting ideas.

In the first place, with what little equipment we Americans had, we did some interesting stunts, as illustrated by one instance occurring in one of the large Enlisted Men's Assembly Halls. Our Y. W. C. A. girls took paper boxes,—typical big Parisian hat boxes,—perforated them with fine hole decorations and supported them beneath the bare lamps, thus giving the first installation of indirect lighting that I had seen in Paris. Then in a hotel bedroom where I lived we had a French lighting fixture consisting of a combination of a good and a bad idea. The fixture itself

consisted of a drop cord that was adjustable so that you could push it up to seven or eight feet, the limit of your reach, and use it for general room illumination; and then there was a counterbalance on the flexible cord, allowing the lamp and reflector to be pulled down for close reading or detail study. It was an interesting and simple idea, and is the kind of fixture you find in almost every hotel in Paris. The bad part of it was that the opal reflector used was so flat that the entire bare lamp was exposed. Glare from bare lamps is a disease that seems to be prevalent all throughout Europe.

One other thought is, that in the best European lighting, as I have seen it, the perfection of the decorative art has been carried out through colored bulbs, and colored shades of silk or paraffin paper, or Japanese types of lanterns, with wonderfully effective results. I do not think I have ever seen a more pleasing instance of this than in one home in Nice, where everything from a blue light on a marble statue to a soft rose-colored array of candle fixtures was an evidence of French taste. I mention these just to indicate that if we might borrow lighting ideas, as our own wives and daughters borrow French fashions, we may secure from these sources,—France or England or other neighbors,—some good ideas that may be profitably applied. I am very glad to have had the chance of hearing Mr. Willcox present his ideas and experiences here, and I hope more of us can keep in touch with European conditions, because we can certainly get good ideas and we will be glad to interchange ours if ours are any better.

Mr. Thompson: Let us realize that successful Industrial Illumination depends upon two factors:—

1. The development of an efficient lamp.
2. The manner in which it is handled.

The ultimate success of an industrial installation depends entirely on effective maintenance by the user.

The natural human tendency is to avoid any work that is attended with difficulty or danger, so, instead of placing the large lamps for general illumination at high points where it is more or less difficult or awkward to properly maintain them, would it not be far better to provide safe and easy access to the same.

Mr. Willcox speaks of "rise and fall pendants" which are used in England; my thought is that such devices, so constructed as to conform to underwriters' requirements, permit of easy access to the lighting unit for cleaning and renewal.

An extensive use is promised for a device permitting the lamp to be lowered to the floor for cleaning, preferably without any long dangling loops of wire to come down with it, and there are such devices where the lamps simply drop away from the circuit when lowered—leaving the wiring undisturbed, enclosed if desired, and when the lamp is pulled up again it automatically comes back into the circuit and locks.

This method of installing the large high lamps has already been adopted in some large Industrial plants, Railroad shops, etc., and the results have been so satisfactory that the practice is rapidly growing.

MR. STICKNEY: I would like to ask Mr. Willcox if the high intensity street lighting extends beyond the main central streets. From information received several years ago, it is my recollection that it was the practice, in London and elsewhere, to provide strong lighting on principal streets, but that the intensity fell off very abruptly, and rather poor lighting was provided on less important streets, while interurban roads were practically unilluminated.

MR. WILLCOX: Answering Mr. Stickney's question, the street lighting in England is confined almost entirely to the city areas, with high intensity lighting in the central part of the cities and towns, which, by the way, is of much higher intensity than in this country, and necessarily so, because of the foggy atmosphere of English cities. As you go out from the central city districts, lower intensity lights are used until you get to the roads where there are no lights at all. The railway locomotives in England run without any headlight at all. With fog so thick that you could not see your hand in front of you, I have seen locomotive engineers run their trains at full speed without any apparent difficulty. Automobiles, however, carry headlights just as they do in this country.

OPPORTUNITIES FOR EXTENDING LIGHTING THROUGH NEW APPLICATIONS.*

R. M. SEARLE.

There appears to be considerable opportunity for increased effort on the part of the central station, the lighting engineer and the contractor towards introducing more and better illumination and discovering day time applications of artificial lighting. One of the striking possibilities in the evolution of lighting is the application of more light in large units.

STREET LIGHTING.

With satisfactory street lighting on the main arteries of travel, the side streets are usually poorly illuminated, although the speed rate permitted often exceeds that of the main avenues. Here is an additional field for large lighting units, a demand which must be met to provide for safety and for convenience. Streets where the speed limits are not and for obvious reasons cannot be strictly enforced, demand better illumination and should have it.

It is important that we develop the possibilities of inter-state, inter-county, inter-town, inter-city and inter-village lighting of main arteries of travel. To-day with high pressure gas pipe lines paralleling many highways and electric transmission systems radiating all over the country, and mostly following the highways, we should avail ourselves of these existing facilities for urging the increased use of electric or gas illumination for state and other intercommunicating highways outside of urban property.

The lighting equipment of the automobile falls short on requirements needed for the purpose of being able to proceed safely at usual speed, say thirty to forty miles an hour after dark, where no street lighting exists. A great many of you will not admit ever having driven your car that fast, but you have done it and you can do it with comparative safety at night if the right lighting and road conditions obtain.

DISPLAY LIGHTING.

The day-time lighting of show windows is another field for mutual advantage to the merchant and the central station.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

FLOOD LIGHTING.

In a tour about six weeks ago, passing through Gloversville, New York, I saw two banks illuminated nightly by flood lighting. Those banks were illuminated all night long. The buildings stood out beautifully. Even the banker is beginning to acknowledge the value of lighting for advertising purposes.

The war brought out and developed the benefits of flood lighting generally, for yards, ships, the loading of ships, ship docks, factory yards, buildings, playgrounds, parks, recreation centers, outdoor dancing platforms, bathing beaches, athletic fields, and so on.

LIGHTING OF FREIGHT TERMINALS.

Another need for adequate illumination is in the lighting of freight terminals, classification yards, loading platforms and so on. That is a splendid field and there is more or less of it done in every yard. The value of artificial lighting as a protection to property is emphasized by the statement of Detective Burns who said he would rather have one arc light than two patrols.

INDUSTRIAL LIGHTING.

We are still far below the saturation point of factory lighting. With less than six months of proper study I believe that lamps still larger than the largest now used can be developed and thousands of them placed in factories, properly screened to reduce glare to a minimum.

STAIRWAY LIGHTING.

The lighting of stairs in public places, large buildings, industrial plants, hotels, theatres, halls and even homes has been rather neglected. One would be astonished to observe the very many instances where people are constantly stumbling because of misplaced lighting units, poor illumination or lack of illumination at these very important points. The present practice in Pullman cars is well worthy of consideration. Those green lights along the base of the aisle way give just the illumination required to avoid stumbling over the numerous grips, suit cases etc., which necessarily clutter the aisles of sleeping cars.

Stairway lighting is a subject in itself and deserves the serious attention and efforts of the Illuminating Engineering Society.

LIGHTING FOR COMMUNITY AFFAIRS.

To illustrate another possibility of increasing the use of artificial lighting, I want to commend to central stations a kind of community co-operation based on our experience in Rochester, N. Y. That is to participate liberally in every civic or quasi civic function or entertainment in your city. Even in the preparation for small church affairs or socials where perhaps there are forty people in attendance, the churches are lighted up for weeks during the rehearsals, the forty homes are more or less lighted until midnight and restaurants are kept lighted for those people to go out and get a midnight supper. So with thirty, forty or fifty functions going on every night in a city, there is, as a result, considerable extra demand for illumination.

PROGRESS.

I have had the satisfaction of having seen pretty nearly the whole course of the evolution of electric lighting (in 1883 I was Mr. Edison's office boy, and as you know, the office boy is more important than his employer generally.) I remember very well Mr. Edison's struggle with the early incandescent lamp. But even with all the progress since that time we are always facing some development which when it comes upsets our equilibrium and we have to begin over again. That is progress. That is as it should be. I can recall the consternation with which our company viewed the Mazda lamp when it first came into use. The sale of current was then largely for light. The question was whether we were going to lose two-thirds of our income because of the possible economies due to the use of the Mazda lamp, but we quickly realized that the course for us was to educate our customers to make use of all the additional light available and then demand more. We purchased some thirty thousand Tungsten lamps and undertook to provide all our streets, stores and buildings with increased illumination with specially designed fixtures, giving them even more than their old wattage equivalents but giving it to them in a manner calculated to improve their display and general merchandising operations. Under this plan the store windows became so bright that the use of larger lighting units became necessary in the doorways. By this course we were able to foster a real demand for more light and we did in fact supply more current to the merchant than formerly.

Gentlemen, our whole effort has been to convince the consumer that he receives excellent returns from his lighting equipment and can get even greater returns if he will let us advise him. We have never harbored the belief that there can possibly be a saturation point in good lighting as such a belief would tend to destroy initiative in the lighting field.

DISCUSSION.

Mr. Friedman: The central stations have an unlimited field in a highway lighting, and with the increase in the use of automobiles and motor trucks there is bound to be a demand for more and better highway lighting. I know of one stretch of approximately twenty-four miles, that is already lighted with 100 candle-power lamps. The lighting is not quite as good as it might be, but it does show a big effort along the line of highway lighting, and I think if central stations will give a little more attention to this subject they will be agreeably surprised at the results.

With the present controlling devices they are in a position to operate these systems with very little attention, a condition which did not exist a few years ago, and it is really a simple proposition for central stations to get in touch with the townships in their vicinity, especially where a central station is operating in the center of a number of small towns. Very frequently they already have their pole line from the central station to a number of small towns and it would be a comparatively simple matter to run a series wire along the pole line and illuminate the highway.

Mr. Israel: I am convinced that there is a big field for the lighting of show windows during the day time. I can recall instances, in earlier days, where certain merchants were doing this for advertising purposes, when we thought that they had simply forgotten to turn the current off but when we did come to look at the idea from their standpoint, we discovered that this extra lighting which might appear to be unnecessary and wasteful had a unique advertising value which the merchant, as a rule, is quick to grasp.

Mr. Cravath: I think the principal reason that shop window lighting has not been used more during the daytime is that it is

very difficult to avoid objectionable reflection from the street in many cases interfering with a clear view of the goods, and in order to overcome that reflection from the windowpane it is necessary to have our artificial illumination at very much higher intensity in windows. Probably several hundred feet candles an effectively lighted window on a sunlit street would require artificial ventilating systems to carry off the heat from the lamps in the upper part of the show windows. It is not impracticable, but it is something we ought to study, and in view of the great values of show window space in some of our large cities the merchants can well afford to be interested.

Mr. Macbeth: I recall an experience in show window illumination some years ago in checking up with the proprietor of a certain store he informed me by having his windows lighted in the daytime he was getting more direct return and more calls for materials shown in those windows than he was from his newspaper advertising. I am merely trying to get this back to a question of increasing the intensities necessary for window use during daylight hours. His windows at that time were lighted with an intensity of approximately five times that advised by our engineering booklets from the lamp companies. He was getting returns from those windows more satisfactory and to a greater extent than from his rather extensive newspaper advertising.

On the subject of further reaching out and uncovering new places for application of illumination I was amazed to be consulted some time ago by a man who desired an equipment to produce about a four foot area of illumination in which to accomplish the matching and selection of cucumbers. That was his sole business. He told me that he was a commission merchant and that his day began at two or three o'clock in the morning and was over about eight. He said, "If I can have my cucumbers properly sorted, my greens and yellows, I can obtain a better price for them and this equipment is going to help my turnover."

I recall another case where operators in a munition plant had been doing what they called a bridging operation. They had a cast iron plate about eight inches long by one and one-half inches with small holes down through the center of the plate, and through those holes are projected pieces of No. 14 copper wire.

It was very fine work and they had been working only in daylight. They had never found any artificial lighting means that worked satisfactorily and by the use of a proper color of light we succeeded in making that thing satisfactory. We are going further than that and bringing our equipment that will take care of more or less the reds and greens and various other spectrum points. It is a service that is worth a great deal.

There are a great many opportunities all through the field, but we must study our subject and be ready with suggestions for special application of illumination in these numerous cases.

MR. MINICK: The field of railroad lighting offers plenty of work for the Illuminating Engineer in both new and old problems. Not many railroads are equipped to properly solve their lighting problems.

The railroad man's time is taken up largely with the manufacture and sale of transportation and lighting becomes one of many incidentals.

Not many realize the occasion for color matching work in railroad service. Practically all railroads paint their cars some characteristic color, and on repair work this color should be matched; it is a convenience to be able to do this under artificial lighting altho such work is usually done in the open during daylight hours.

Classification yard lighting has received considerable attention but lighting systems have changed so rapidly of late and the improvements made have been so favorable that there seems to be strong promise of still further advance.

One of the latest developments along this line is the use of flood lights mounted on poles 70 to 80 feet high. This system permits simplification of the wiring and the use of multiple burning service. The current consumption remains however at about what it would have been if individual lamps, scattered throughout the yard had been. In as much as the width of freight yards does not vary greatly, the current consumption is somewhat proportional to the length of the yard. About five watts per foot length of yard appears to be a fair average for present day practice in yard lighting.

The tendency, in repair work, is to go to larger and larger shop buildings which brings with it complications in shop lighting. I have in mind a large building used for the repair of locomotives in which the ceiling height is 80 feet. The locomotives are spaced so as to give a working aisle of about 15 feet in width between locomotives. Local conditions and methods of handling work are such as to prevent the use of the side walls and columns as supports for lighting fixtures except as a last resort and at great expense.

Such problems as these are peculiar to railroad work, and I appeal to Illuminating Engineers who interested to take up the study lighting as applied to railroad service, and I am sure they will find in this a broad and interesting field of endeavor.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XV — APRIL 30, 1920 — No. 3

STREET LIGHTING WITH LOW MOUNTED UNITS. KENSICO DAM ROADWAY.*

BY C. A. B. HALVORSON AND A. B. ODAY.

The Kensico Reservoir which is located east of the Hudson River about 30 miles approximately north from the New York City Hall (see Fig. 1) contains several month's supply of Catskill water and acts as a storage reservoir so that the flow of water into the city will not be interrupted while the 75 miles of acqueduct between it and the Ashokan Reservoir are being inspected, cleaned, or repaired. This reservoir is an artificial lake formed by the Kensico Dam across the valley of the Bronx River about 3 miles north of White Plains, N. Y., near the village of Valhalla, N. Y.

An idea may be gained of the magnitude of the reservoir and dam from the following statistics taken from a report of the Board of Water Supply of New York City.

STATISTICS OF THE KENSICO RESERVOIR.

Approximate amount of contracts	$8,500,000
Capacity, total	38,000,000,000 gallons
Water surface	3.5 sq. mi.—2,218 acres
Length of shore line	40 miles
Main dam: total length	1,825 ft.
length of masonry portion	1,825 ft.
height (maximum)	307 ft.
thickness at base (maximum)	235 ft.
thickness at top (minimum)	28 ft.
depth of reservoir (maximum)	155 ft.

The arts of structural and landscape architecture, have been employed to make the entire construction a work of beauty, in keeping with its magnificent proportions and the Great City of New York.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, October 20 to 23, 1919 Chicago, Ill.

The Kensico Dam is a gravity masonry structure of cyclopean concrete. The up-stream face is of concrete blocks. The concealed portion of the downstream face below the final grading was molded against forms, above which the remainder of this face is of cut stone masonry. The entire dam is divided into sections transverse expansion joints about 79 ft. apart longitudinally

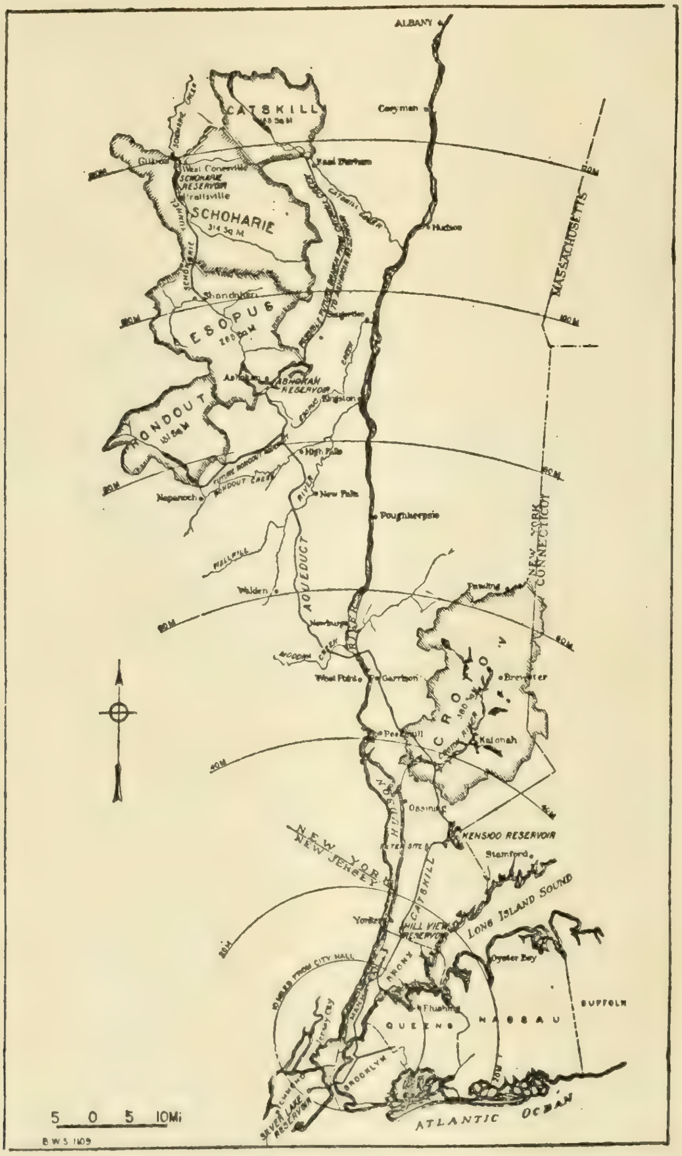


Fig. 1.—Map of Catskill Water Supply System, New York City. The development of this water system is considered to be an engineering achievement second only to the Panama Canal.

These expansion joints are faced on one side with concrete blocks forming a series of vertical tongues and grooves against which the masonry of the other side was built.

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Fig. 2.—View of Upstream face of Kensico Dam.

g. 3.—Daylight view of roadway along top of dam showing circular pavilion at end and parapets in which are located lighting units.

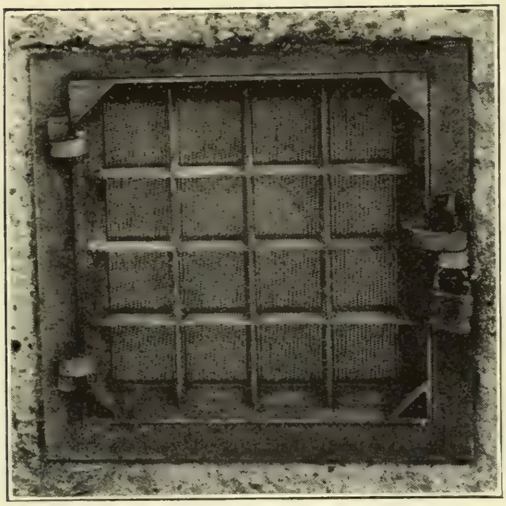

Fig. 4.—Exterior view of lighting unit showing casting and construction of paneled door.

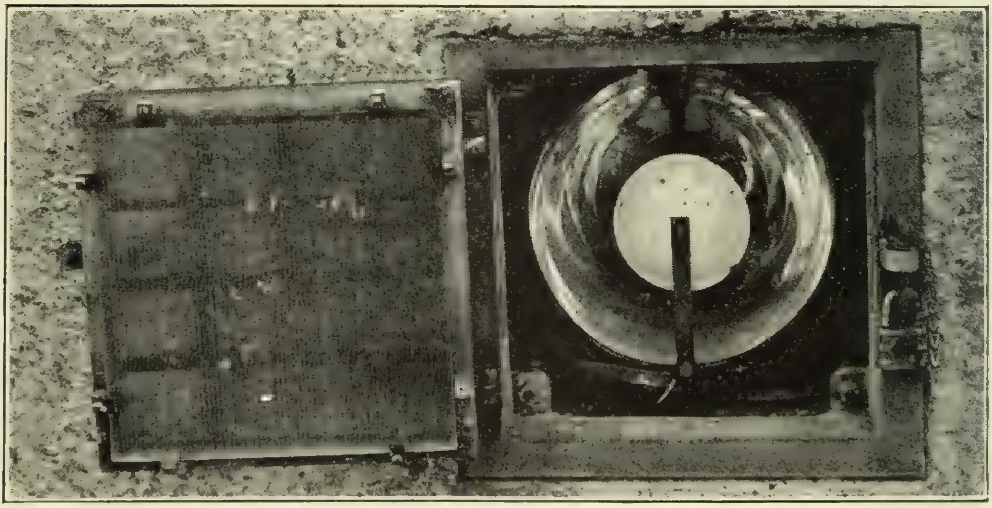

Fig. 5.—Interior view of lighting unit showing prismatic glass door, reflector and baffle in position.

The down-stream face of the dam was given a dignified architectural treatment in harmony with engineering fundamentals. For the profile of the downstream face a true hyperbola was adopted. Since the dam is divided for structural reasons by twenty-two expansion joints, its down-stream face has twenty-one panels and two terminal structures. At each expansion joint there is a massive band of rusticated stone, 15 ft. wide, projecting boldly from the general surface. These bands separate the panels, the fields of which are of roughly squared stone masonry, surrounded by borders 3 ft. 6 in. in width of dimension stone cut to relatively flat surfaces. To add interest to the panels, dimension stone headers about 1½ ft. square are spaced throughout the fields to a diamond pattern and set to project slightly. (See Fig. 2.)

A public highway, carrying considerable automobile traffic, traverses the top of the dam, approaching from the east over a three arch masonry bridge across the nearby waste channel of the reservoir. Each terminal of the dam is surmounted by a circular pavilion of granite.

The part of the roadway crossing the top, a daylight view of which is shown in Fig. 3, is approximately 2,200 ft. long and 26 ft. wide. It is bordered on one side by a sidewalk about 4 ft. wide. At either end of the dam are located two pavilions surrounding a circular court. The roadway is brick paved and runs between cut stone parapets approximately 4 ft. in height.

The architectural specifications for this dam would not permit the use of poles in connection with a lighting system of the roadway. It was, therefore, decided that the lighting should be provided from ports located in the side of the parapet wall. The designing architect conducted experiments with apparatus consisting of candles and boxes, and concluded therefrom that a lighting system could be developed for the roadway which would not require the use of poles. As a result, provisions were made by permanently locating recessed openings cut in the stone work. These openings were approximately 13½ in. square and 15 in. deep, spaced approximately 37½ ft. apart and located on both sides of the roadway with a staggered arrangement of spacing. The centers of the openings are 26½ in. above the surface of the roadway.

After the dam was completed, preliminary tests of various lighting equipment which were tried out indicated the necessity of the development of a special system of illumination which would require specially designed devices. It was recognized that the roadway could best be lighted by triangular sheets of light. It was further required that as near an approximation of even illumination as possible be provided. There must not be objectionable glare and the distribution of light must be such that the usual requirements of good street lighting be met as far as possible with the units located in these unusual positions. Lighting units designed to meet these requirements are perhaps best described by quoting from a copy of the original specifications which were drawn up after the preliminary investigations and tests.

SPECIFICATIONS FOR UNITS FOR LIGHTING ROADWAY ON KENSICO DAM.

General. 1. "The complete units must be neat in appearance and of weather-proof construction. They must be capable of long continued operation without additional protection.

Complete Unit. 2. "Each unit shall comprise a reflecting device with baffle and mounting, a dispersing door and a transformer.

Reflectors. 3. "The reflecting device shall consist of a mirror of good quality clear glass silvered on the back with the silvering protected by a heavy uniform electrolytic deposit of copper. This copper coating shall extend over edges of the glass so as to clinch the copper and there shall be not less than 10 ounces of copper on each mirror. The mirror shall be approximately 11⅛ in. in vertical diameter and 10⅞ in. in horizontal diameter, and shall be the shape that is obtained when a series of conical frustra, each ⅝ in. in width, is cut by a plane parallel to the axis and ⅛ in. distant, the smaller portion being used, and two such joined together. The sections of conical frustra above mentioned shall be such as would be tangent at their middle points to an inscribed parabola of 2⅛ in. focal length. This mirror shall be attached to a substantial metal mounting having three points of support, two of which shall be adjustable for the purpose of obtaining necessary control of the beam of light from socket adjustable in a direction parallel to the axis of the reflector, sufficient range being provided so that by the use of an adaptor for medium screw base, 108-watt,

> 72-watt or 36-watt lamps may be used. There shall be a curved baffle attached to the mounting above described and located directly in front of the lamp so as to screen direct rays from the lamp filament. This baffle shall be made of sheet-iron with white, fire-enamel surface on the side next to the lamp, and shall be hinged or otherwise secured so that it may be removed when renewing the lamps or cleaning reflectors."

There is a cast metal frame of suitable size to fit the opening in the parapet wall, carrying a hinged door which is fitted for supporting the prismatic glass. This door is provided with a lock and has four bars across the front for the purpose of protecting the glass. These bars are ¼ in. wide and ½ in. deep and are cast complete with the door itself and arranged symmetrically, two vertically and two horizontally. The dispersing glass in the door consists of one piece of sheet prism glass with the prisms placed vertically. It is attached to the door by means of screw clamps. The function of this glass is to give some diffusion and give additional spread to the beam of light so as to produce uniform illumination over the surface of the street.

The source of light consists of a 6-volt 108-watt Mazda "C" headlight lamp. As these lamps operate at a very high efficiency and are designed for shorter life than is considered practicable for street lighting service, it was deemed desirable to operate them at a somewhat lower efficiency than rated. Consequently, power is supplied by means of individual transformers giving 5½ volts. Operating at this voltage, the lamps will consume approximately 94 watts and give an average life commensurate with those designed for street lighting service. Figs. 4, 5 and 6 and 6A show in detail the location and construction of the lighting units.

In addition to the ones used on the roadway, similar lighting units supply illumination for the terrace along the base of the dam.

An idea of the distribution of light obtained from the lighting units is shown by Fig. 7. These curves show the distribution of light in the horizontal plane and above the horizontal in a vertical plane, perpendicular to the parapet. There is a very wide spread of light in the horizontal plane and consequently, the illumination over the whole roadway and parapet walls is comparatively uni-

form. The vertical distribution shows that the illumination falls off rapidly above the horizontal and that at the eye level of an automobile driver, the intensity is comparatively low. The above curves were obtained by measurement of one unit only with a portable illuminometer, and therefore, may not give an accurate representation of the overall efficiency of the lighting unit; however, they do show the general character of the distribution obtained.

The curve in Fig. 8 shows the horizontal illumination along the center line of the roadway surface to be quite uniform. Critical observations of the lighting effect show it to be adequate to meet the usual requirements of first class highway lighting and agreeable to travelers.

The night views, Figs. 9 and 10, show the illumination results obtained, the former being taken looking along the level of the roadway while the latter was taken at a considerable elevation.

A system such as described above, may or may not be practical for the lighting of ordinary streets or roadways, depending upon conditions and requirements. However, the results obtained in this particular case are gratifying and may form a basis for other installations of similar requirements. The power consumption is not prohibitive (approximately 5.0 watts per running foot of roadway) the illumination is of sufficient uniformity, there are no poles to mar the architectural beauty of the structure, light is confined and distributed so as not to be objectionable from the standpoint of glare—all of which are factors that have considerable bearing in striving for the ideal of the illuminating engineer.

Comparing the practical results obtained and the theoretical considerations involved, it may be of interest to review the various phases in the development of the lighting unit finally adopted. At first, it was thought that the main requisite was to confine the light to the surface of the road with a sharp cut-off at the horizontal. It was found, however, by installing units on a model road with canvas sides which simulated the parapet walls that this did not meet the requirements.

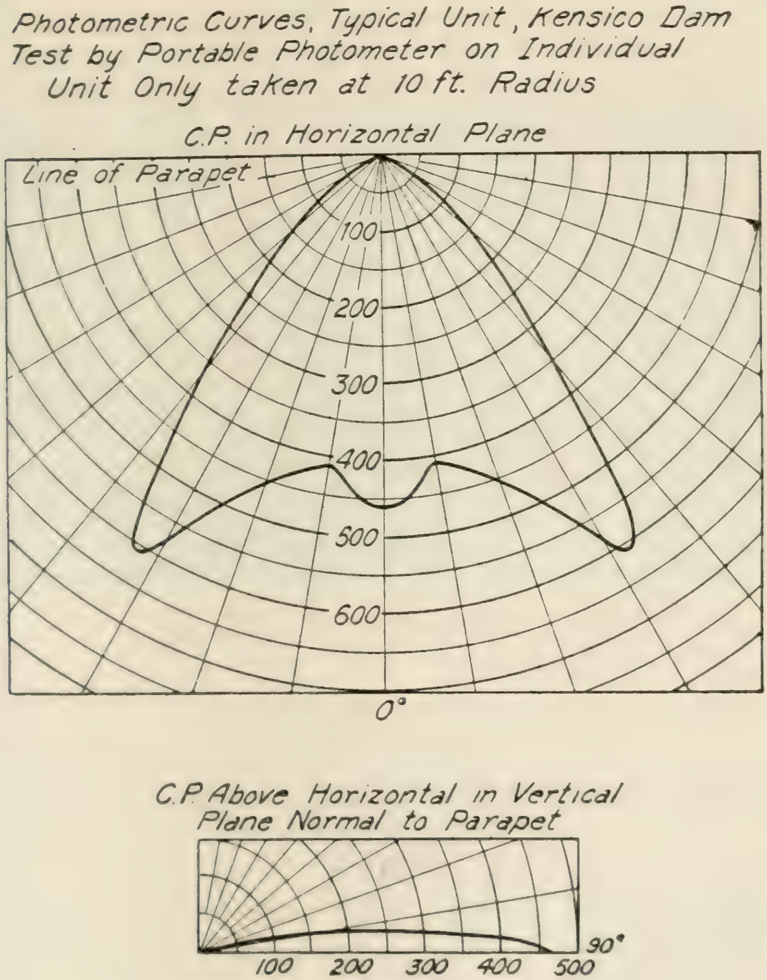

Fig 7.

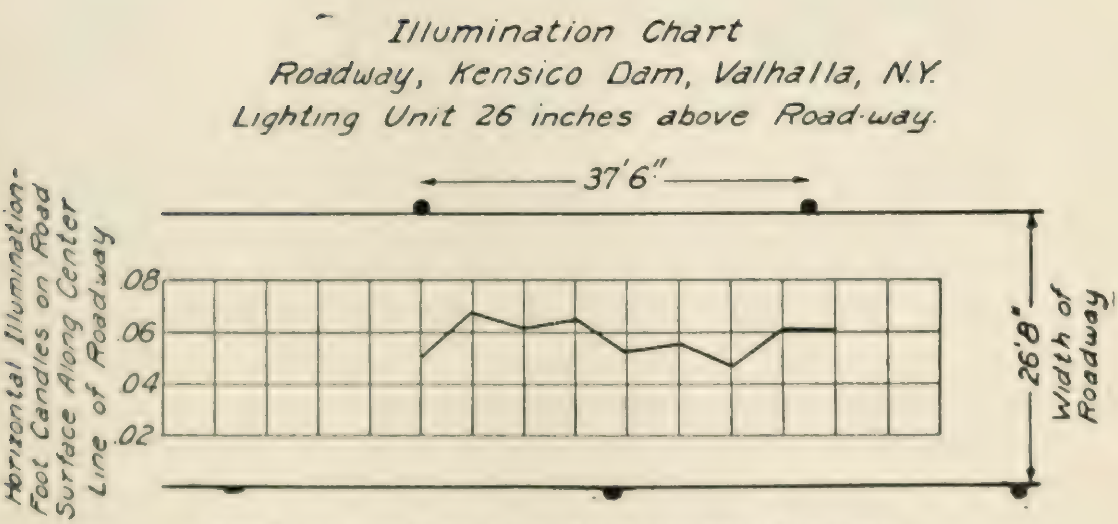

Fig. 8.—Horizontal illumination along center line of roadway.

The lighting units from such a system were glaring due to contrasts between them and the adjacent wall, and further, objects gave the appearance of being cut off due to lack of light above the level of the lighting unit. To eliminate these objectionable features, each fixture must throw sufficient light on the parapet wall opposite to relieve the contrast between the light source and adjacent parapet wall. An agreeable balance in this respect was finally arrived at after a series of visual tests. The necessity for this is clearly indicated by the lamps shown on either side of the entrance in Fig. 10. In these cases there was no opportunity to project light on the parapet wall; hence, by contrast the lighting units appear more dazzling than those on the main roadway.

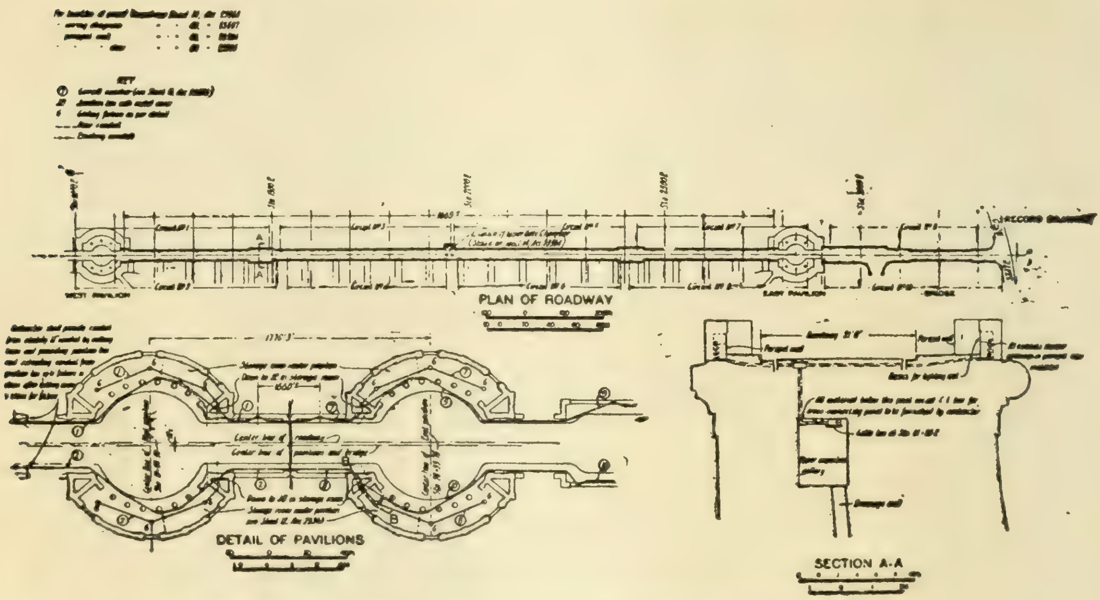

Fig. 11.—Details of roadway showing location of lighting units.

The idea of using low mounted units for street lighting is not new. It had been suggested by various engineers for parkways, bridges, etc. but grave doubts had been expressed as to its practicability. This successful application demonstrates the possibilities.

The success of the installation is in no small degree due to the thorough and persistent efforts of Mr. J. Howard Williams, former Mechanical Engineer of the New York Board of Water Supply, under whose direction the details were worked out. Es-

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Fig. 6.—Interior view of lighting unit showing baffle lowered.

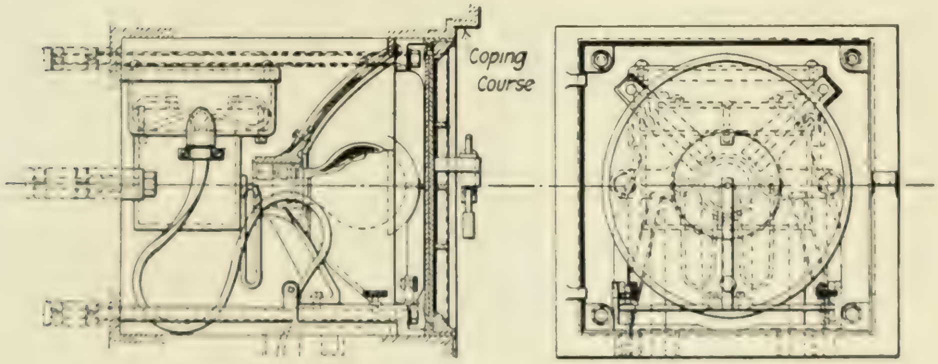

Fig. 6-A.—Section and plan view of lighting unit used on roadway showing details of construction.

Fig. 9.—Night photograph looking along level of roadway showing illumination results obtained.

Fig. 10.—Night photograph looking down upon roadway.

pecially, during the early study of the problem, Mr. H. A. Tinson, now of the South African General Electric Company, gave much useful advice.

The authors desire to acknowledge the assistance rendered by Mr. R. C. Ewry, the present Mechanical Engineer of the Board of Water Supply, through whose courtesy arrangements were made to obtain photographs and test data.

DISCUSSION.

Ray C. Ewry, Mechanical Engineer Board of Water Supply: To Mr. J. Howard Williams, who was mechanical engineer for the Board of Water Supply during the inception and construction of the above lighting units, belongs the credit of making possible *the* development of what is a new departure in street illumination. To quote his own words, he remarks that "when representatives of the General Electric Company and tthe Board of Water Supply were brought together, little was known in regard to such a problem, as no opportunity had ever been had to install and operate a similar display."

The final design of the lighting unit proper, with its reflectors and refractors and source of light, was due to the efforts of Mr. Halvorson, who worked to reach the ideal condition which the Board of Water Supply wished to obtain. The design was hampered, undoubtedly, by the fact that it had to be made to fit in a predetermined opening in the parapet, this condition being imposed by the fact that the structure of the dam was completed prior to the enlistment of the services of the General Electric Company. At that time, it was not known what shape and size would be required.

The lighting results to be appreciated fully must be seen. Photographic illustrations of the lighting effects at night, while fine examples of the photographic art, do not convey the proper effect of the illumination. Especially of note are the effects obtained by the two end units which illuminate the faces of the pavilions as shown in Fig. 9. These units are of value as they show clearly the possibilities in this form of unit in illuminating not only a low parapet wall, but also in illuminating to almost any desired height, this result being obtained by properly fitted diffusing glasses and slight tilting of the unit.

The field of light in the horizontal plane of one of these units, is necessarily triangular in outline. The continuous lighting of the roadway in the top of the dam is effected by staggering the exposed units, resulting in one solid bank of light the entire length of the roadway. In the terrace at the foot of the dam, there are installed similar units along the one parapet facing the dam structure. The doors of these units are not flush as in the case of the roadway ones, but project outward in the form of a "V", which shape permits of a larger spread of the lighting field, and a better distribution of light along the line of the parapet. This arrangement results in darker space showing between each light when viewed from a distance, but when the observer passes along the terrace, there is but little difference in lighting power noticeable.

The system as installed on the dam structure, in my opinion, marks a big advance in the illuminating field, and the actual conditions of operation and the effects observed should be of value in the installation of other systems where their application would be indicated.

DEVELOPMENTS IN STREET LIGHTING UNITS (ELECTRIC).*

BY A. D. CAMERON AND C. A. B. HALVORSON.

General.—During the war, street lighting suffered both in operation and in development. The fuel conservation movement and the general unsettled conditions mitigated against any appreciable extensions of street lighting systems and most illuminating and designing engineers were engaged in research and development work for the Government.

With the signing of the armistice and the termination of the war, the demand for street lighting has reopened. Old systems are being overhauled and refurbished to repair the neglect of the last two years. New systems are being planned and installed. Designing engineers are at work to meet the new conditions imposed on street lighting apparatus.

The situation is rather paradoxical. The natural reaction from wartime conservation encourages higher intensities and more decorative lighting. The resumption of building activities is adding new streets and new territory to be lighted. The ever increasing high speed vehicular traffic demands better and brighter illumination for our thoroughfares. Increasing costs of material and labor combined with the difficulty of securing adequate rates from municipalities make it hard for central stations to meet this demand. There seem to be several ways of dealing with this problem. First, municipalities must realize that there is no fundamental difference between electrical apparatus and electrical service and any other commodity. They are equally effected by the increasing costs. Daily wages are higher, working hours per day have decreased and the hourly output is less. There can be no compensating decline in the cost of materials because labor is a large percentage in the cost of raw material. Municipalities must realize that street lighting is a public necessity and as such, must receive the proper financial support to keep it effective. Second, central stations may help by selecting the most efficient apparatus and by making use of every method of economical operation.

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, October 20 to 23, 1919, Chicago, Ill.

The higher the cost of installation and maintenance, the more important the efficiency of the system as a whole. Third, manufacturers must help by making every effort to simplify apparatus, substitute less expensive materials and reduce manufacturing operations. The new developments in street lighting, therefore, are not radical and revolutionary in scope but tend toward simplification of apparatus and maximum utilization of light.

Pendent Units.—In the pendent unit for series Mazda lamps, the most important addition is the combination of dome refractors and stippled or rippled outer globes. The refractor when used alone, has not been universally satisfactory, although its use has been very general. The collection of dust and dirt is still serious in some communities. This deposit occurred on three surfaces; the lamp bulb, and the inner and outer faces of the refractor. Where dust and smoke is prevalent and where the glassware is not cleaned frequently, this may account for a 50 per cent. absorption of light. By enclosing the dome refractor in a stippled or rippled globe, only one surface is exposed. In these globes, the diffusion is obtained by protuberances and depressions in the surface of clear glass. This breaks up the light but does not interfere with the directional effect of the refractor. The absorption is practically that of clear glass.

Comparing the stippled globe with the ordinary diffusing globe, it is found that:—

(1) Its efficiency is 15 to 30 per cent. higher.*

(2) Its appearance is better since it is the only glass which lends sparkle to the Mazda lamp.

(3) It permits the use of the Holophane dome refractor, giving three times the light at points midway between lamps.

When the stippled globe and dome refractor are compared with the bowl refractor, there are the following advantages:—

(1) More light—15 per cent. more total lumens.*

(2) Less absorption during operation.
One surface exposed to dust and smoke instead of three.

* Efficiency values given in this paper are manufacturers data. The magnetite electrode data are not finally established, but are best known values to date.

(3) Uniform distribution.
 Directly under the lamp 200 per cent. more light.
 At the 45° angle, 100 per cent. more light.
 At the 10° angle, only 15 per cent. less.

(4) Improved appearance.
 A larger secondary source of light.
 Sparkling—not dead.

There is an attractive installation of these units at Niagara Falls.

Another method of enclosing the lamp will soon be available by the use of a bowl refractor with a closed base. The outside section has diffusing prisms cut on its inside surface. The inner shell has refracting prisms on the upper half only while the lower half is etched. Eliminating the bottom opening effectually excludes bugs and insects while the omission of the refracting prisms on the lower half give a better diffusion at points near the unit.

Ornamental Units.—The single light of high candlepower has proved more popular than the clusters of lower candlepower lamps from a standpoint of economy, efficiency and appearance. The standards themselves are becoming slender and unobstrusive. The new globes for such standards are of more graceful shapes with smaller and top bottom openings and with as low absorption as is consistent with perfect diffusion. New developments show a serious effort to harmonize the architectural features of the pole, casing and top.

Duoflux Units.—The most important prospective development in the ornamental lighting field is an arrangement of two lamps in one globe, one above the other, tip to tip. The lower lamp will be 600 or 1,000 candlepower and will burn until midnight. The upper lamp will be 100 or 250 candlepower and will replace the lower lamp during the hours when the streets are deserted and when a lower intensity of light will be satisfactory. This should be a notable improvement. At the present time, it is necessary to operate the white way all night or to connect the ornamental system in two circuits, alternate lamps in series, and cut out one circuit at midnight. This entails double wiring, a reduction of half the wattage after midnight, a rather spotted appearance on the street and a wastage of light because the remaining units

still light the building fronts as well as the streets. In the new units, it is proposed to use a small mercury cut-out in each unit to which the two lamps are connected. By momentarily reducing the current in the circuit, the lower lamp is extinguished and the upper lamp turned on. Only one circuit is required. The reduction in wattage will be 70 to 80 per cent., depending upon the sizes of lamps used. Each unit will burn and the appearance and illumination will be uniform. Furthermore, if the dome refractor is applied to the upper lamp, it will intercept the upward light and project it to the street surface. This results in an illumination equal to that of a lamp twice the size and permits the use of a very small upper lamp. It is expected that an installation of these units will be completed within the next three months.

Parkway, Boulevard and Residential Lighting.—While pendent units are still used for most of the above classes of lighting, there is an increased demand for more decorative units. Here the conditions are somewhat different than in the business districts. All upward light is either wasted or is a source of annoyance to residents along the street. Here again the dome refractor and the stippled globe are useful. The dome refractor eliminates all upward light. The stippled glass assists in the diffusion and gives a live, sparkling effect. The actual intensity of light on the street surface is 100 per cent. greater than with a round ball globe. Assuming a satisfactory intensity of light, only one half the number of units is required. An extensive parkway system is being lighted by these units in Toledo, Ohio. A typical installation for bridge and viaduct lighting is in operation in Cincinnati, Ohio.

Brackets and Center Span Units.—In an effort to reduce manufacturing operations and to increase the safety factor, there is under development a unit to be moulded of one piece of porcelain. The radial wave reflector and the refractor holder will be integral parts of the whole. This should simplify the question of maintenance and replacement and increases enormously the insulation of the unit.

Another proposed change is a cartridge film for series sockets; so arranged that it does not have to be removed for replacement each time the lamp burns out. The original roll will last for years

under normal operating conditions. It will not necessitate any change in receptacles and can be used in any units of the same make already installed.

Luminous Arc Lamps. Electrodes.—To increase the actual illumination, it has been decided to compound the ingredients of the electrodes under great pressure. This permits a high efficiency mixture, giving approximately 50 per cent. more light than the standard with at least equal life. If the standard intensities are satisfactory, the compressed electrodes will yield an increased life of 30 to 40 per cent.

Reflectors.—With this electrode, it should be possible to use a glass mirror internal reflector which adds a further improvement to the effective illumination. In the unmodified luminous arc 60 per cent. of the light is above the horizontal. The present porcelain reflector while efficient becomes of less value when discolored by fumes. The glass reflector will be initially of higher efficiency and will be more easily cleaned.

Globes.—Pendent luminous lamps have been regularly furnished with clear globes. With the increased light from the new electrodes, it will be possible to use a blown rippled globe which will give an appreciable degree of diffusion and a no higher absorption than the clear glass.

Wattage Adjustment.—The increased efficiency electrodes also permit the use of a lower wattage adjustment on each lamp without materially reducing the effective lighting. This saves 40-60 watts per lamp an dincreases proportionally the capacity of the rectifier. In Detroit for instance, they are operating 90 to 94 low wattage lamps on each 75-light rectifier.

Conclusion.—The simplicity and flexibility of the Mazda lamp has given it a very definite place in street lighting. However, these very characteristics are tending toward a serious situation. With the arc lamp, there was a rather limited downward range in intensity. The Mazda lamp with its variety of candlepower sizes, permits the use of lamps giving intensities totally unfit for good street lighting. Adding to this the increased cost of apparatus and the desire of municipalities to keep down their street lighting budget, there is found a steady reduction in the sizes of lamps

used and a corresponding reduction in the general lighting. Furthermore, with the arc lamp, it was necessary to visit each lamp periodically, replace the electrode and clean the globe. Incandescent lamps are renewed three times a year and in many cities only twice a year. There is a growing tendency to neglect the lamps except at these times, with the result that accumulation of dust and dirt cuts down the light and ruins the appearance of the installation.

There is a steady improvement in the quality and quantity of light in our homes, in stores and in factories. Street lighting standards must keep pace. Lamps of sufficiently high initial candlepower should be selected and replaced when the efficiency has fallen to such a value that it is most economical to discard it. Fixtures must be properly maintained and the glassware periodically cleaned. The entire expense of the street lighting installation goes into the production of light. False economy in maintenance may cut in half the utility of the entire investment.

DISCUSSIONS.

FRANK MISTERSKY: We have gathered such large quantities of information that we don't quite assimilate it all, and do not get the full import and full significance of what we really hear until we get home and go over our papers; and then we are in a position where we cannot ask questions we would like to ask now if we really appreciated what was given to us here. So along that line I would like to give a little information in connection with the changes that have been made in the luminous arc lamp in the reduction of wattage. Detroit, like all other cities, has endeavored to cut down the cost of street lighting without reducing the efficiency thereof. The information was given to us that we could reduce the wattage of our street lamps by about forty watts, by reducing the length of the arc and using a special type of electrode. Not the type that Mr. Halvorson brought out, that is obtained under a higher pressure, but a lamp which would reduce the length of the arc, and compensates for the loss of the illumination by flatting the electrode; thus securing more of the downward lumens. As Mr. Halvorson brought out, a good many of these theories are worked out, the problems are solved in one direction and then we stumble across something that we did not appreciate. We hesitated in Detroit to make the change. How-

ever, we felt that it was worth while, and the first trial was made on a street that is lighted with posts installed on both sides, spaced from 150 to 175 feet. The installation was made; and just to give you an idea of the effect of the lighting of the street when the lamps were first put out, I will give you our experience. When the change was made we wondered if we had done well. Unfortunately, I was busy that night and could not go out. I sent one of my assistants who had been in the street lighting business for a number of years and who lived up in that direction, to go along the street to tell me what sort of results we had obtained. He reported to me the next morning that the improvement was a very decided one. Of course that was due to to the fact that the new lamps were clean and the other lamps of the standard wattage had been at the end of the trim, but all that I wish to call your attention to is this, that in the change of the 7,000 odd, standard adjustment lamps we provided a capacity for over 1,100 additional lamps without additional demand upon the power station, without additional station apparatus and without additional circuits from the station. You can appreciate what that meant to us. I am just calling your attention to this to show you that you need not hesitate to apply these modifications; because the results are excellent and we are saving a lot of money by it.

J. W. COWLES: Just a word of personal experience with one of the recent developments described by Mr. Halvorson and that is the units employing the new glassware known as stippled or rippled glass. A few years ago when we started our gradual process of changing from arcs to incandescent lamps we were confronted from the start with the objection raised against the incandescent lighting from its entire lack of sparkle. life and animation which has always been so characteristic of the arc lamps. In general, perhaps we hated to admit this fact, but we had to admit it because the fact was beyond dispute. The old irregularities of the arc lamp which were held up sometimes as objectionable to the arc we were really surprised to find had been one of the assets of the arc, and that little animation and life and sparkle which is so characteristic of the arc lamp was noticeably absent, objectionably so, in the incandescent units. From our experience thus far, with an installation recently of the new

Mazda units with the rippled glass we have every reason to believe that the old objection is well eliminated and that the incandescent unit today has a sparkle and life and animation which is all that need be desired with immense improvement to the general appearance and attractiveness of the unit. On a semi-suburban thoroughfare recently widened and resurfaced, we have an installation of this nature and the results, I believe, are going to be very satisfactory, In this particular case, while the street is very spotted due to too great distancing of the lamps, yet the fact remains the lighting of the thoroughfare is excellent and from a traffic standpoint I believe it is going to prove very satisfactory. Personally, I have had no experience as yet with the rippled glass in distinction to the stippled glass. I have not yet been convinced as to the superiority of it from the standpoint of lighting service, but it is obvious that it has advantages, marked advantages, which may on the whole make it fully as satisfactory as the other form of glassware in the stippled form. Just a word of warning is always in order I believe on the old problem of cleaning the units, the glassware, particularly with incandescent units where there is no regular visiting of the unit as in the case of the arc lamp. I would like to point out one fact, that has been noticeable in some directions, an attempt to incorporate into specifications or regulations laid down by the city or included in the contract perhaps, periodic cleaning of the glassware at pre scribed periods. That, I do not believe is a logical procedure from any standpoint. The cleaning must of necessity depend tremendously, upon the conditions, such as the nature of the traffic on the street, whether it is a dusty street or otherwise, the importance of the street from various standpoints, the season of the year so that any stereotyped or contracted specification as to the cleaning periods is far from meeting the requirements in my opinion, and the cleaning must always be based upon a most careful consideration of the conditions and with intelligent effort to meet those conditions as they may appear.

LOUIS BELL: One of the outstanding facts which looms above everything else in the general trend of this series of papers is particularly interesting to one who has been in the game for a good while, and that is that the big, powerful, high-efficiency incandescent lamp and the arc lamp have gone on developing

side by side, each adapted to its own field of usefulness and each one capable of working that field to better effect than the other. Six years ago I was told by one of the great arc light engineers on the Continent in tones of despair: "I have worked for twenty years developing the arc light, and it is gone, gone." The arc light has not gone, as the evidence before us to-day very plainly shows. Wherever small distributing units are necessary the incandescent, thank goodness, has come to an efficiency which none of us have reason to be ashamed of and which we can freely utilize, but the arc lamp has gone on, too. The arc lamp where very high intensities are desired, as for the lighting of plazes is holding its own after that cry of despair of six years ago. Furthermore, the arc lamp has been increased in efficiency almost as much as has the incandescent lamp in the same period, so that it bids fair to hold its own in the big units for a good while to come, in spite of the doubt that was cast upon it. Furthermore, there is one advantage that I have seen, a collateral advantage, perhaps one not altogether pleasing, and that is that merely from the fact that you have to trim the arc lamp once in a while, at intervals which have been steadily growing longer, you do have to go to that lamp and you clean it up. No matter how carefully you draw a contract for the cleaning of incandescent lamp fixtures there is nothing which drives the man running the lamps to go to those lamps unless his attention is called to them. My experience has been that if you go through any city, however well lighted with the big incandescents, and they do magnificent work, and I use them in my own practice very freely, when you go to such a city you have to watch out to see whether the globes have been kept clean. The big arc lamps automatically have their globes cleaned because you have got to go to them about once in so often, and a man is very negligent who won't take advantage of the opportunity to do a little work in purification, by the easiest means at hand. I think it is a tremendously interesting fact that the two illuminants have gone on improving, increasing in efficiency, increasing in general usefulness and each fitting into its own sphere, the incandescents of high power to the general lighting of a great many places that do not require the highest intensity and greatest brilliancy. Where that is desired, we have not yet found anything that is

better than the high power, high efficiency magnetite lamp. All this simply shows the resourcefulness of the inventor and the skill of the adapter in meeting all the conditions of street lighting with two radically different, yet each extremely useful, illuminants.

H. B. VINCENT: Dr. Bell and the last speaker have neither of them mentioned the question of the burning hours of the lamp. To my mind it has as much bearing on the question that has just been discussed as the cleaning of the globes. I would like to raise the question from the standpoint of a commercial operating man whether they have any schedules, (*i. e.* predetermined schedules) when they shall change their lamps. I have been in a position in the last few years to keep data in connection with the life of the type C lamps and I find with operating men there is a tendency to let the lamps go until they go out. I have had cases as high as four or five thousand burning hours for the lamp and you know what that means with relation to candlepower.

WARD HARRISON: At the risk of repetition I want to indorse the remarks of Mr. Halvorson and Dr. Bell on the subject of maintenance of incandescent lighting systems. I believe that the ideal of many a street lighting department has been to obtain a lamp that could be put out on the street and thereafter let alone until some accident on the post from which it hung made replacement necessary. Some believed when the incandescent lamp arrived, that they very nearly had it, but so far as I know there is no line of human endeavor, whether in the home or in business, from which the drudgery of a periodic clean-up can be eliminated without disasterous results. The attitude which must be taken in the case of street lighting is that units of every type must be cleaned, and the aim of the manufacturer of the fixture should be to make this maintenance as easy as possible. Mr. Halvorson brought out the point that the use of a globe around the lamp helped materially in this respect. Our early experiments in Cleveland show that the absorption of the globe was a negligible factor in comparison with the loss of light that otherwise occurred due to dust and dirt; and this is particularly true in the case of units which follow the modern trend of using more and more scientifically designed reflecting and refracting devices about the light source.

Our first experiments in this direction were with a globe treated with the familiar crackling or ice etching process. This crackling, by the way, furnishes a very convenient means of procuring a globe which will give the effect of breaking up the light rays without materially altering their direction, especially so in experimental work where a small number of globes is involved and it would not be practicable to make a special mold. The units with crackled globes around the refractor showed an average candlepower on the street decidedly higher than that obtained from the ordinary band refractor fixture. The development of the stipple globe, although superior to one of crackled glass, proved to be considerably more expensive, because at that time we felt it necessary also to have the stippling on the inside to remove it so far as possible from contact with the dirt laden atmosphere, and this necessitated a pressed globe. Mr. Halvorson's modification of using a blown rippled globe, with the rippling in vertical lines so that dust will tend to blow off and wash off, promises to have still greater popularity on account of its lesser cost. The final design will depend upon whether or not the collection of dirt on a rippled globe is accomplished more rapidly than on one with a smooth exterior.

There is one point relative to the development of better street lighting which perhaps has not been investigated so far as it should be, and that is, the relation of street lighting to traffic accidents. A short time ago we sent a man to the police headquarters in Cleveland to get a record of all accidents which had occurred during the past year,—somewhere between 3,000 and 4,000. Our first step was to list the accidents occurring in the late afternoon hours in mid-summer when we had good light, and to compare the totals with those occurring during the same hours in mid-winter when it is almost totally dark. There were 25 per cent. more accidents between 5 and 9 o'clock in the mid-winter months than in the summer months between the same hours. It might be said that the difference was due to slippery pavements or to a change in traffic conditions, or perhaps some other cause, but comparing the accidents in the daylight hours between 9 A. M. and 4 P. M. in both summer and winter, we found an opposite condition obtained and that the summer accidents were more numerous by 10 per cent. Again, taking the

hours around midnight in summer and winter, we found that the summer accidents were approximately 10 per cent. more frequent. So that it seems clear that there would actually be more accidents at all hours in summer than in winter, except for the question of light. Going one step further, we took the best lighted section of the city and segregated the accidents which occurred within its limits. We found that instead of their being 25 per cent. more accidents between the hours of 5 P. M. and 9 P. M. in the winter, than in the summer, there were actually but 5 per cent. more in this district. If those in other cities who are interested in street lighting should go to their own police department records and make a similar investigation, the mass of data so accumulated would perhaps prove to be more convincing than any other argument which might be advanced for good street lighting.

W. T. DEMPSEY: On the question of maintenance, Mr. Chairman, in the New York installation of about 20,000 globe enclosed units, we have regularly laid out cleaning routes where each one of the lamps and globes is cleaned within definitely stated periods, and at approximately two weeks interval. These are regularly laid out routes and is the system followed there. In the Mt. Kensico Dam installation, it would be of interest to know the dimension between the center line of the lighting source and side walk grade.

RECENT DEVELOPMENTS IN GAS STREET LIGHTING.*

BY F. V. WESTERMAIER.

While the subject of Street Lighting has been discussed in a number of able contributions to the TRANSACTIONS of this Society, very little has been said in regard to the factors governing street lighting practice. As it is an important field for the application of illuminating engineering principles, some references to the controlling conditions imposed by general practice are of value in describing progress made toward the desired ideals.

Light has been recognized, from the earliest days of communities, as an effective protection against crime, and, as civilization progressed, the main idea of street lighting as a policing agency has prevailed. In the earliest days when flares were used, as in the present times of modern gas and electric illuminants, grave concern has been given to provide for the continuity of lighting service so that it should not fail during the hours of darkness.

Of all the public services, rendered by municipalities, there is probably none more essential for the preservation of public safety, the comfort and peace of mind of the public, than street lighting. It is a service which must be as continuous and as complete as the life of the community itself. This involves responsibility of a high order and is so recognized by the directing authorities in the drafting of specifications for the work to be done.

Curiously enough, although street lighting is essentially a municipal service like the Police and Fire systems, it is very rarely operated like these departments, by the municipality itself. It is dependent, first of all, on the lighting product of the local gas and electric companies and, secondly, on the maintenance operation of the lighting fixtures furnished. And because of this dependence on the local public utilities and their recognized responsibilities in the community, municipalities generally regard

* Paper prepared for presentation before the Thirteenth Annual Convention of the Illuminating Engineering Society, Oct. 20 to 23, 1919, Chicago, Ill.

street lighting service as an obligation on them to perform and not as a business proposition in the same light as contracts for public works.

In some cases street lighting service is required of the utility corporation under the terms of the franchise and the remuneration, if any, fixed for the period. The general method, however, is to issue specifications covering the service to be rendered, including the plant and materials to be furnished, over a given contract period. The utilities are expected to bid on the established plan, the appropriations for which are sometimes made or budgeted prior to the opening of the bids. Many of these specifications are never changed, being repeated year after year along the same lines of furnishing and maintaining so many fixtures, replacements of lamps, changes of fixture locations, lighting, extinguishing, cleaning, etc., on a unit price rate. In fact, owing to the inflexible nature of many street lighting systems, changes in specifications to carry on service with them would not always improve illumination results, unless such changes provided for alterations to the existing systems. As this involves increased expenditure, it is seldom if ever done. The prevailing attitude of municipalities toward street lighting is and has been to reduce instead of increase the appropriations therefor; extensions are generally made only where, in the opinion of the local authorities, absolute necessity demands them.

Specifications for electric street lighting almost universally combine the furnishing of fixtures and maintenance service with the supply of current, while for gas lighting, bids are usually asked for the furnishing, and maintenance of fixtures, separate from those for the supply of gas.

In short, general practice confines street lighting to the application of service to plans usually laid out more for protective than for illumination purposes and limited by the public funds appropriated.

Notwithstanding the handicaps imposed, there has been considerable progress made in improving the illumination of streets through the use of more efficient lamps, improved fixtures, and, wherever possible, the adjustment of such parts of the street lighting plan to obtain the greatest advantage with the newer fixtures.

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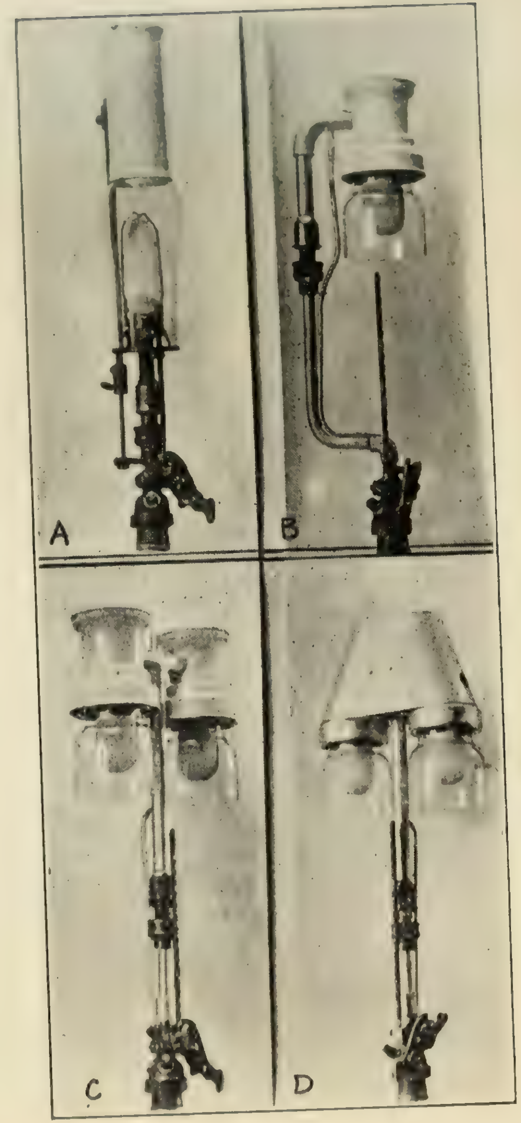

Fig. 1.

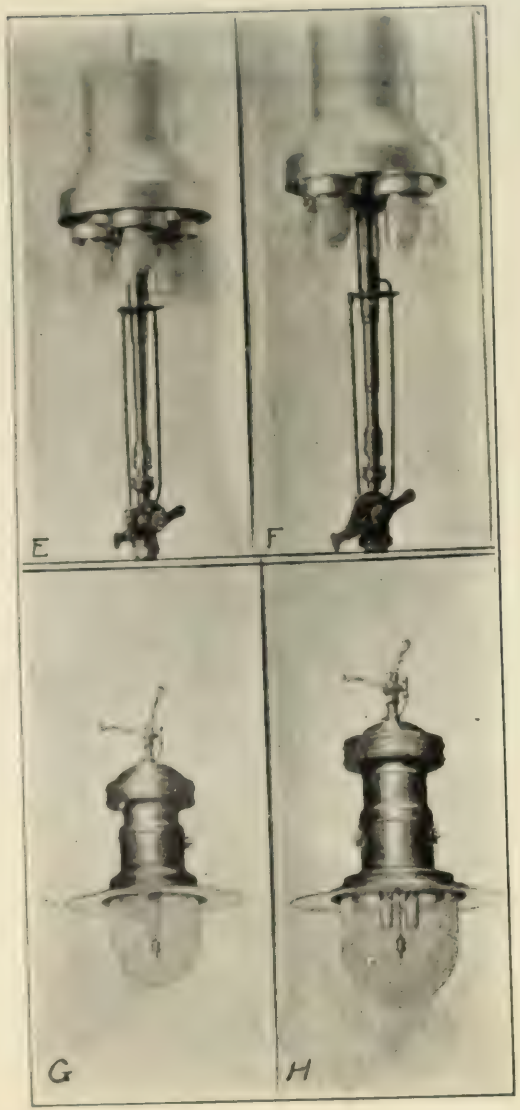

Fig. 2.

Fig. 3.

Fig. 4.

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Fig. 5.

Fig. 6.

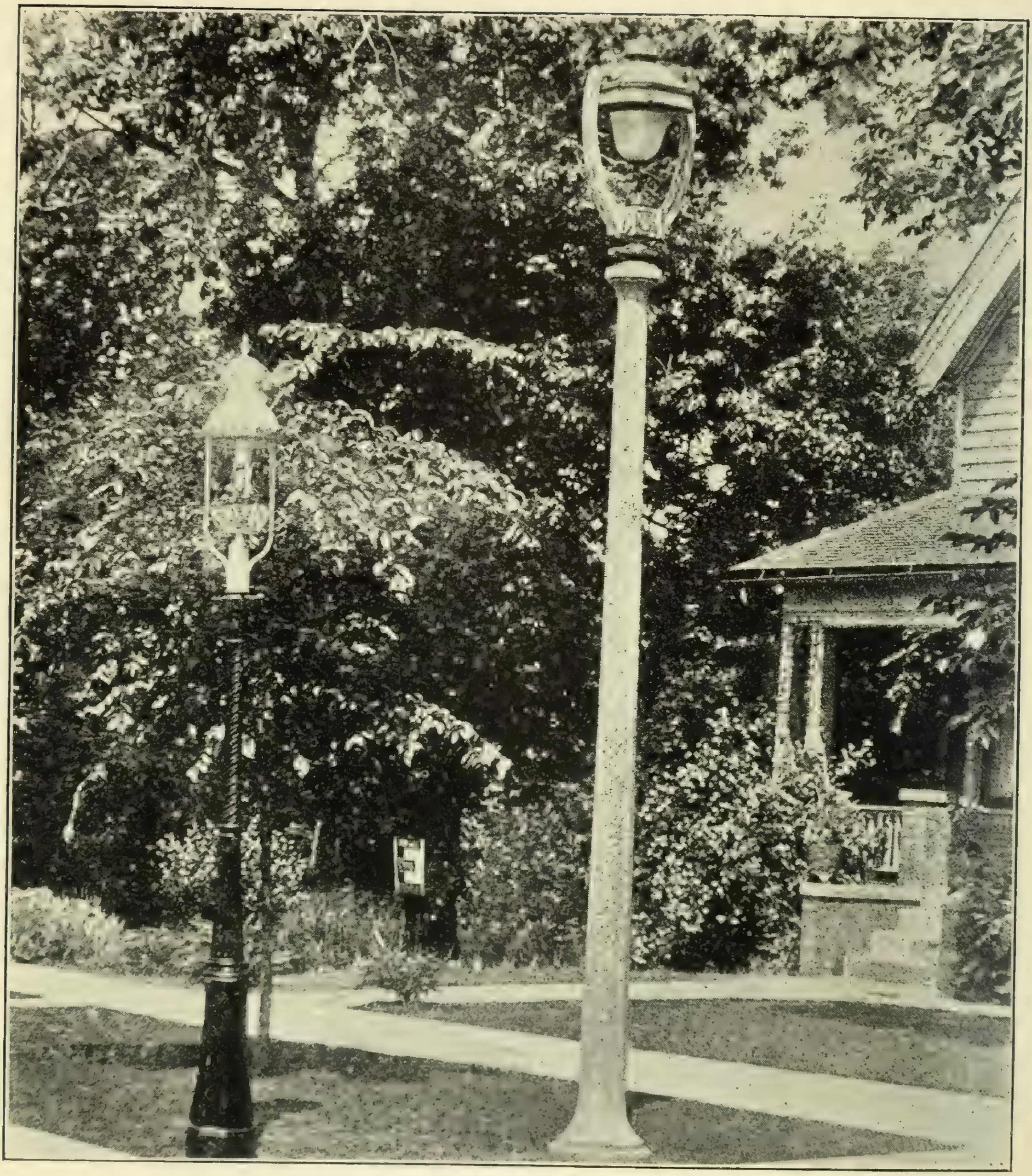


Fig. 7.

The object of this paper is to deal particularly with recent developments in gas street lighting practice along these lines.

The separation of the supply of gas from the maintenance of fixtures is largely responsible for the development of standardized fixtures and lamps, and service. Figs. 1 and 2 show substantially the types of lamps most generally employed.

These are standard types but are adjustable to the particular quality of gas on which they are used, and to the provisions of contract specifications fixing the candlepower delivered and the rate of gas consumption.

At first glance, these lamps may appear rather complex but as a matter of fact they are quite simple. The necessary elements are as compactly combined as possible, consisting of gas cock, automatic gas regulator and injector, Bunsen burner, mantle, chimney and chimney accessories.

The illuminating powers of the different lamps shown, are as follows:

	Lamp	Lumens per B. t. u.	Total lumens
Fig. "A"	Single mantle upright	.300	630
" "B"	" " inverted	.400	720
" "C" & "D"	Double " "	.410	1,475
" "E"	Triple " "	.420	2,200 to 2,500
" "F"	Four " "	.420	2,950
" "G" & "H" are types of high pressure gas lamps operating under gas at 2 pounds per square inch.			
" "G"	Single mantle..............	.525	3,775
" "H"	Double "	.525	8,400

The values for the high pressure lamps are given in order to show the effect of pressure on efficiency, in lumens output per B. t. u. applied. Claims of considerably higher values, .750 to .900 lumen per B. t. u., have been made by foreign manufacturers of larger types of lamps than those shown here.

High pressure gas street lighting has not been encouraged in this country as in Europe where it is very extensively used. The most notable installation in America was that at the Panama-Pacific Exposition during 1915 in San Francisco. While its advantages are apparent there is not sufficient revenue obtainable

from street lighting alone to warrant the expenditures necessary for the installation of special mains and fixtures.

Because of variation in the quality of gas in different cities, according to the manufacturing processes employed, the adjustment of the standard type lamps to the local conditions is important. This involves determinations by tests to fix the setting of the gas regulator, its injector size, Bunsen proportions, and provisions for auxiliary air regulation to meet, within limits, any variation from the average quality of gas furnished. From the determinations made, a standard burner balance, for that particular locality, is obtained and every lamp used there is made to conform to that standard.

The automatic control of the rate of gas consumption is not a recent development, but its application is an essential part in all the latest lamps designed. This controller, after it is adjusted to the local gas conditions, automatically maintains, under all variations in main pressure, a constant pressure below the fixed outlet injector orifice. It thus makes possible, not only an accurate accounting for gas used, but also the maintenance of a constant flame within the mantle, thereby tending to produce uniform candlepower intensity.

In addition to the essentials for producing most efficient burning qualities the lamps are designed to meet the requirements of service conditions; operation, trimming, replacement and interchange of parts.

The development of artificial silk mantles, both upright and inverted, for street lighting purposes has done much to improve and maintain the service. Not only are they stronger than those formerly made of cotton and Ramie fiber but they retain the initial candlepower values throughout the greater part of their life. Another characteristic is that they do not shrink and therefore always fit the flame. For service reasons the mounting of mantles has also received very careful attention. Upright mantles are now held in position, on the carrier caps, by nichrome wires, thereby eliminating the oxidation and subsequent failure that formerly occurred with nickel-steel supports, and the tying on of inverted mantles to the magnesia rings is reinforced by weaving into the asbestos cord a very fine wire of nichrome.

The general uniformity in the height and design of gas posts throughout the prevailing street lighting systems made it possible to standardize lantern design in the familiar gas Boulevard type shown in Fig. 7. This lantern contains all the structural features necessary for the proper mounting of the gas mantle lamps, also to provide the necessary ventilation and protection against storms and drafts. It serves as the basic principle pattern for all new lantern designs, which must conform to be efficiently serviceable.

The general tendency to improve the appearance of street lighting fixtures makes standardization extremely difficult because of the diversity of opinion as to what constitutes harmony of design in the combination of a standard and a lantern. As a result, a large number of different styles of fixtures have been designed, all of which have advocates as well as objectors. There seems, however, to be one point of agreement, in view of the numbers of installations made in various cities, which is, that the upright type of lantern is more generally preferred than the pendant.

Figs. 3 and 4 show installations of two different styles of fixtures each equipped with double inverted mantle lamps similar to Fig. "C". The globes in both cases are of diffusive glass, producing a pleasing, soft illuminating effect.

Before the suggestion to improve the lighting of the street, shown in Fig. 4, could be put into effect, it was necessary to gain the approval of the local Art Jury which made the selection of the fixtures used.

The need of lighting fixtures for directing the flow of street traffic has been supplied in several ways. Two styles are shown in Fig. 5. The fixture in the center foreground consists of a rather low standard mounted on a concrete base and topped by a globe of ruby flashed glass. In order to illuminate the standard and base, the flashing is cut away in the lower portion of the globe. As a matter of interest, it might be mentioned that when ruby glass became unobtainable, a satisfactory substitute was found in a special paint preparation which when used on clear glass globes gave equivalent results.

The other type of traffic fixture is shown in the center back ground consisting of two pendant globes with inverted mantle

lamps. This type also, spreads clear light over the ground around the standard and base but to a more considerable extent than the other type and is generally utilized, on this account, in open spaces where the side illumination is low. The globes in this type are of ruby glass with the lower section cut away so as not to obstruct the clear light from the lamp in the lower zones.

Another special fixture type is shown in Fig. 6. Here a bronze bracket with pendant globe is attached to a concrete trolley and aerial transmission line pole, for the lighting of an important thoroughfare; a viaduct, into which four or five street grades are merged. The application of the standard double mantle gas lamps to the bracket fixture as designed, seemed at first an almost impossible task because the lines did not admit of any change to provide for the necessary ventilator. However, although the design had been approved and designated for use by the Art Jury, the construction was not begun until a way was found out of the difficulty which proved very satisfactory. In short, what could not be applied externally was taken care of in the construction of the interior and the assembling of the different castings, so that the full efficiency and service value of the lamp was maintained without changing the lines of the original design.

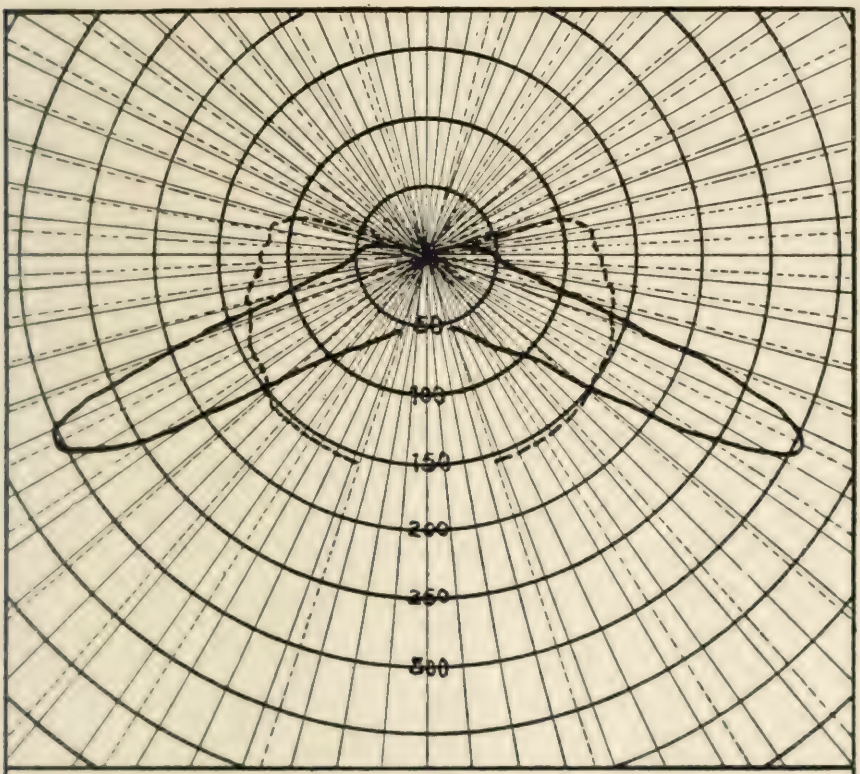
These fixtures are mounted 16 ft. high and are so spaced that the illumination produced is remarkably uniform and of a satisfactory degree.

The service qualities demonstrated by the fixture for this particular class of lighting recommended its use for the lighting of another and longer viaduct of similar type in the same city.

Although extensive surveys have been made in a number of cities for the purpose of obtaining more efficient street lighting plans, very few have been fully realized, principally on account of the cost involved. Principally among those that have adopted entirely new systems are, Milwaukee, and the village of East Milwaukee, Wis.

In laying out these systems the engineers decided first on a definite classification of streets and then the application of fixtures designed to produce substantially uniform illumination. In both cases the use of gas as well as electricity was considered. The adaptation of a specially designed single inverted mantle

lamp to the Refractor fixture adopted was accomplished with excellent results. In Fig. 7 is shown one of the new fixtures photographed along side of the former gas Boulevard type. As the identical fixture is used for both gas and electric, 1,000 lumen lamps, the interchange of respective illuminants throughout the system is possible, maintaining at the same time the uniformity desired.



POLAR CURVES
• SHOWING •
DISTRIBUTION OF LIGHT FROM AN INVERTED GAS MANTLE FIXTURE USED IN CONNECTION WITH A NO 4430 HOLOPHANE REFRACTOR

Fig. 8.

The type of inverted mantle lamp designed is particularly applicable to Refractors and the resultant efficiency, about 90 per cent. in lumens output, is high. The lamp is adjustable to the focal center of the Refractor so that any desired projection of the maximum beam can be obtained. A characteristic polar distribution curve of the bare lamp is shown in Fig. 8, also the

result produced by the No. 4430 refractor with a given position of the mantle light source. It is seen that the maximum flux of light from the inverted mantle falls within the enclosing refractor which explains the high degree of efficiency obtained.

In the future development of street lighting practice, it is certain that the application of scientific illuminating principles will become more general as municipalities grow to appreciate their real practical values.

Those who have confidence in the peculiar fitness of gas as a street illuminant, because of its reliability and service qualities, believe that through the joint co-operation of all those engaged in street lighting service this aim will be attained to the immeasurable benefit of the public served.

NOTE: Owing to the delay in the receipt of the manuscript at the General Office, the author was unable to read proof of paper before printing.

DISCUSSION.

C. M. MASSON: Mr. Westermaier in his paper in speaking of silk mantles said that the candlepower remains practically similar up to the end of the life of the mantle. I would like to know whether the life of a silk mantle is any different from the life of a cotton mantle, either inverted or upright.

F. V. WESTERMAIER: Of course, the life of the mantle depends a great deal on the amount of traffic on the street. You might have to make as many replacements of silk mantles as you would of cotton mantles because of the particular vibration that you might have on that street, but generally speaking the silk mantle has a longer life.

C. M. MASSON: About what is the life of the silk mantle as compared with the cotton mantle under ordinary conditions?

F. V. WESTERMAIER: Well, the cotton mantle will run probably on an average about 450 hours, whereas the silk mantle would probably run, under the same conditions about six or seven hundred hours.

C. M. MASSON: May i ask one more question? What would be the candlepower of a cotton mantle after about 400 hours?

F. V. WESTERMAIER: A cotton mantle made particularly for street lighting purposes—there is a distinction between commercial mantles and street lighting mantles, a very marked distinction. The best grade of cotton mantles used for street lighting will at the end of about 300 hours have depreciated about 25 to 30 per cent. The silk mantle will start off initially on the same rate of consumption as the cotton mantle with a lower candle power but after the first 100 hours it has increased in candlepower up to about 110 per cent. or 115 per cent. of its original value, its initial value. I have records of tests where the life test has been continued for five or six hundred hours where the candlepower of the silk mantle has always been above the initial candlepower value. The silk mantle is a big improvement over cotton or any fiber mantle for street lighting.

F. V. WESTERMAIER (In reply): As you probably noticed, the principal part of my paper was taken up in the discussion of street lighting in general. One cannot be engaged in one branch of municipal work, such as street lighting, without feeling a certain amount of responsibility for all that is being done in street lighting. The points that I brought up were intended to show the restrictions placed upon street lighting development. We have not developed in street lighting as rapidly as we have in other branches of illumination on account of those restrictions. I believe, in view of the remarks made here by those discussing the various papers, that one of the most important factors in street lighting is becoming more generally recognized and appreciated by those who have to do with it, and that is, maintenance. Maintenance costs money. It was probably on account of the cost of street lamp maintenance that gas companies long ago gave up any idea of extensively going into street lighting work. The result is that gas street lighting service is now divided between the supply of energy and the maintenance of units. If it had not been for the strict attention paid to the maintenance of gas lamps, with illuminants originally so fragile in nature, there would be considerably less than the quarter of a million gas street lamps that are being operated in the United States today. The progress of street lighting abroad is based on its importance for illuminating as well as police purposes and is

indicative of the results that good maintenance will bring forth. Some of us who have had the opportunity to compare the extent of street lighting, here and abroad have been forced to admit that Europeon cities are generally better lighted because the value of street lighting is more thoroughly recognized and appreciated. Just so soon as our central station companies and all those who are engaged in street lighting work appreciate, to the fullest extent, the important effect that good maintenance has on the development of this necessary field of illumination, then street lighting will advance as is should for the greater benefit of the community. No one here probably recognizes the difficulties that have beset gas lighting in particular. It has been held back in a great many instances by prejudice based on ignorance, but there is one outstanding fact, and that is wherever gas street lighting has been properly maintained, it has gone on; it has been systematized maintenance that has kept it alive. Likewise it will be the maintenance given the electric light which will help it to go ahead so that some of the excellent ideas which the Illuminating Engineering Society has fostered for more and better street lighting will come into practical use.

HISTORICAL SKETCH OF STREET LIGHTING*.

BY PRESTON S. MILLAR.

NOTE ON EARLY ILLUMINANTS.

The firebrand was probably the light source of prehistoric peoples. It was an incident of heating rather than an illuminant. Possibly the first real artificial illuminant consisted of a torch of selected resinous wood as distinguished from other wood burned for heating.

Lamps of antiquity—common objects in museums—evidence the use by the ancients of animal fats and oils for illumination. These are shallow vessels to contain oil in which the wick was dipped. Such lamps have been described as producing "a little light, with much sputtering and stinking smoke."

Near the close of the twelfth century the tallow candle of sheep's fat came into use in England. Experiments, 1811 to 1831, led to the stearine candle which did away with much of the smoke and disagreeable odor of the tallow dip and gave more light.

Argand, in 1784, developed the round wick centra-draught lamp. Quinquet, in the following year added a glass chimney. The resultant great improvement in the utilization of animal and vegetable oils produced, for the first time in history, a satisfactory lamp.

Mineral oil was burned experimentally for illumination during the first half of the nineteenth century. Discovery of petroleum in Pennsylvania in 1859 led to revolution of the oil lamp industry. During the next few decades mineral oil largely superseded other oil for illumination.

Progress in the development of illuminants has been more rapid than progress in their use. In practice each one has survived by many years, *sometimes by centuries, the development of a superior illuminant.*

* Paper presented at meeting of New York Section in New York City on April 8th, 1920.

PRIOR TO THE NINETEENTH CENTURY.

The historical writings listed in the bibliography make it possible to trace the evolution of street lighting. The earliest street lighting was accomplished by torches (links or flambeaux) borne by the wayfarer. The principal object was protection against highwaymen, and to this end the torches contributed to the assistance of an armed guard.

Torches continued to be the principal reliance for street lighting until the eighteenth century although candle lanterns were used in the sixteenth century and came more generally into use until the perfection of the oil lantern. In modern times the highest development of the portable street light is the automobile headlamp, the lineage of which traces directly to the ancient torch.

Fig. 1.—A night journey before the time of fixed street lamps.[3]

The early lanterns are described as a circular framework of metal or wood containing a candle which was protected from wind by translucent material, either parchment, hog's bladder or thin cloth. Candles were usually of tallow, though sometimes of the more expensive wax.

In 1318 there were three fixed lanterns in Paris.[2] One was in a cemetery. A second was at the door of the Chatelet. A third was hung over the Seine as a mariner's light. In 1408, to celebrate the entrance of the Bishop of Liege into Paris, it was ordered that each street should have a lantern for that one night. A year later, on account of popular disorders, lanterns were again placed in each street. These appear to have remained for about four years when they were discontinued.

186 $\frac{1}{2}$

Fig. 2.—Parisian night watchman with candle lantern, sixteenth century.[2]

Fig. 4.—(Note artist's strange ideas of light distribution.)[2]

In 1525 the inhabitants were ordered to place a lighted candle in a front window of each house at nine o'clock. This expedient, and that of lanterns hung in front of houses during certain nights of the year, was adopted in a number of the principal cities of Europe during the sixteenth century.

Important developments took place in the lighting of Paris in 1558. On October 29th it was ordained that citizens should place a falot at each street intersection and that a watchman supplied with a light should be stationed in one house to the right and in one house to the left of each street. The falots were to burn from ten until four. They consisted of vessels filled with tallow, resin or other inflammable material, and were the equivalent of the cressets mentioned later in the account of street lighting in England and America. On November 7th these were replaced by lanterns. There were at that time about five hundred streets in Paris and the lanterns numbered about 1500. This system did not prove successful, for on February 21st, 1559, the lighting equipment was dismantled and sold. Whatever may have been the shortcomings of the materials of illumination, it appears that the chief cause of failure lay in the dependence upon unorganized citizens for the installation, operation and maintenance of the lanterns.

About 1575 the wife of Henri II caused statues of the Virgin to be erected at important street corners. These were furnished with iron cups to hold oil and wick. For a short period these were lighted most of the night. We may here discern a first step in the development of so-called "flood lighting."

In 1594 renewed attempts were made to light the streets of Paris by fixed lanterns. These were only partially successful because reliance was again placed in citizens for maintenance of the system. At this time we may note a significant milestone in the progress of the art, namely, the first use of glass in street lanterns.

Throughout the early history of street lighting there may be noted frequent references to the use of torches and lanterns for festive occasions and celebrations. At such times light seems to have been employed lavishly.

The year 1662 was rendered notable by the entry of the public service corporation into street lighting. A lantern rental and

torch bearer (porteflambeau) service was instituted with established rates and with "service meters." The charge for lantern rental was about three cents per quarter hour. An hour-glass was provided to measure the lapse of time and to prevent disputes.

Fig. 3.—Lighting of statue in 1575.[2]

La Reynie, Lieutenant of Police, achieved considerable fame as a street lighting engineer. In 1667 he reorganized the fixed lighting of Paris. Under his supervision the 912 streets of the

city were lighted by 2736 lanterns. One was placed at each important street intersection and in the longer streets an additional lantern was placed midway. These lanterns were bucket shaped and contained candles weighing about one-quarter pound each. On the outside was painted a rooster as a symbol of vigilance. Lanterns of this general type continued to be installed until about 1745. The total number in Paris in 1721 had reached 5772.

It was natural that artificial light was employed first on moonless nights. Not the least of La Reynie's claims to fame is his employment of street lanterns in 1667 "even during moonlight"! One hundred years later Mercier indulged in much satirical comment on the absurd parsimony which was responsible for the continuance of the moonlight schedule. From that time down to the present men have not ceased to rail against such unreasonable restriction of street lighting, but it was La Reynie who first abolished it in the district under his jurisdiction.

The practice of mounting lanterns over the middle of the street appears to have been adopted very early in the history of the use of fixed lanterns. When the lighting system failed in 1559, the lanterns "ropes, poles, etc." were sold. This would seem to indicate that some of the lanterns at that time may have been suspended from ropes stretched across the street. At any rate La Reynie in 1667 suspended the lanterns from ropes stretched between pulleys attached to opposite houses. The lanterns were about sixteen feet high. This practice of mounting lanterns from ropes over the street was followed during the next two hundred years.

Oil lanterns for street lighting came into use early in the eighteenth century and thereafter gradually displaced candle lanterns in such service. No little engineering skill was devoted to their development during the next hundred years, and the record of the utilization first of animal oils, then of vegetable oils and finally of mineral oils is in itself an interesting history.

In 1745, 23rd of December, Matherot de Preigney and Bourgeois de Chateaublanc obtained the privilege of an enterprise for new lanterns furnished with oil and *polished metal reflectors* called "reverbere." Here is a development of the very highest importance in the history of street lighting!

This was followed in 1763 by another significant advance. There was held a competition at the Academie des Sciences to obtain a plan for "the best way of lighting a large city, ensuring as far as possible safety, economy and duration." Chateaublanc won the prize with a modified and improved form of his reverbere.

The use of these reflectors in street lighting gave rise to discussions which would not be out of place in a meeting of the Illuminating Engineering Society. Chateaublanc declares in his memoires that the light from his reverbere was so intense that a person could be recognized 30 paces away. Numbers of people, however, found the light too brilliant, and complained that it tired the eyes of passers-by and blinded coachmen and horses. Chateaublanc retorted that if some eyes were blinded by his lights it was because they gazed at them with too much admiration. It was not necessary to look at his lanterns, which were suspended 25 to 30 feet high. Their attention should be directed to their feet and surroundings. As to the coachmen, they should be looking at their horses, while the horses themselves could not easily walk with their heads in the air. Thus did this prototype illuminating engineer deal with the earliest discussion of glare in street lighting!

The company which was organized to light the streets with oil reverbere lanterns contracted to repair and substitute new lanterns, furnish oil of tripe and hire the lighters for an annual payment of about $70,000. This street lighting, being entrusted to a company especially organized to administer it, proved satisfactory. M. Sartine says: "The light diffused by this reverbere is so brilliant that it is impossible to think that the future has in reserve anything better!" In 1780 Mercier wrote: "There have been no more lanterns for sixteen years, the reverbere have taken their place. In former times 8,000 lanterns with badly placed candles extinguished by the wind or melted, lighted badly or gave a pale, uncertain light interspersed by shadows, shifting and dangerous. Today means have been found to give great light to the city and also great facility of service."

In 1777 the road from Paris to Versailles was permanently illuminated. Five leagues and a half of reverbere. Never had such an illumination been imagined. Mercier exclaimed: "No city, ancient or modern, has offered utility on such a scale!"

Following is a specification of the earlier reverbere: "Hexagonal frame of iron without solder. Those of five lights shall be 2 ft. 5 in. in height including the cap. Diameter, 22 in. at the top and 16 in. at the base. Those with three or four lights must be 26 in. high including the cap. Those with two lights will be 24 in. in height, 17 in. in diameter at the top and 9 in. at the base. All the lanterns shall have their lamps of different sizes in proportion to the time they will be lighted. Each light shall have a reflector of copper, silver plated, and each lantern shall have a reflector placed horizontally over the light which shall be the whole size of the lantern to prevent shadows. This reflector shall also be of copper, silver plated."[2]

THE CRESSET-BEARER.

Fig. 5.—A cresset bearing public watchman.[5]

At the end of the eighteenth century there were 5624 reverbere in Paris. These continued in use until displaced by gas lamps. Portable lanterns or links were, however, used extensively at the close of the eighteenth century.

The early history of the lighting of London is much like that of Paris. At first the street lighting was incidental, consisting of feeble illumination from candles placed in windows; or from

occasional lanterns hung in front of houses; or from the flickering torch of the night watchman or a chance passer-by. About the middle of the thirteenth century regular night watchmen were provided. These carried cressets or open barred pots containing inflammable material and mounted upon the end of a long pole. Fig. 5 is a reproduction of an old print showing such a device in service. The pot is hung in swivels fastened to a forked staff. In the center of the pot is a spike about which is coiled a rope soaked in pitch or resin. When ignited the cresset produced a little light with much sputtering and smoke.

In the early part of the fifteenth century attention was given to securing some improvement over occasional peripatetic lighting and in 1416 the Mayor of London ordered the more prosperous householders to hang lanterns in front of their houses from Allhallows to Candlemas (November 1st to February 2nd). These were to be provided with "fresh and whole candles." A print of a Jacobean bell-man in the British Museum bears the following legend and indicates that this practice continued for at least two hundred years after the order was promulgated.[4]

> "A light here, maids, hang out your light
> And see your horns be clear and bright,
> That so your candle clear may shine,
> Continuing from six to nine;
> That honest men may walk along
> May see to pass safe without wrong."

At the end of the sixteenth century night watchmen carried horn lanterns.

Pepys' diary, about 1666, makes numerous references to links and linkboys. Thus—"with a link, it being about ten o'clock, walked home", "so with a linkboy, to Scott's"; and "after supper, with the young ladies, bought a link and carried it myself till I met one who would light me home for the link. So he light me home with his own, and then I did give him mine."

From 1668 until the end of the seventeenth century fixed lights were few and ineffective. They consisted chiefly of candles which municipal regulations compelled householders to place in front windows or of lanterns in front of houses. In time longer lighting hours were prescribed and lighting was required a greater number of nights per year. But always the principal demand

ON THE
LATE INVENTION
OF THE
NEW LIGHTS.

——*Velut inter Ignes*
Luna minores. Hor.

IN dogrel Rhimes we ſeldom uſe
To ſtay for any God or Muſe:
But in ſo nice a caſe as this,
I think it cannot do amiſs:
For all the Link-boys round the Town,
Have ſwore, I hear, to run 'em down:
The men of Tallow, Wieck, and Cotten,
The Tin-men too, the Cry have gotten.
Whom, let me ſee, ſhall we retain?
PHÆBUS, for once, ſhall be the Man:
Great God of LIGHTS! we Thee invoke,
If not by t'other Side beſpoke;
The Stars above, to Men below,
But like your Farthing-Candles ſhow:
Whilſt Thou with Glorious Luſtre crown'd,
Do'ſt hang like one of Six i'th' Pound:
Thou, who'rt *All-Eye*, caſt half an one,
Down on this NEW INVENTION:
'Tis New indeed to us below,
But known in Heaven long ago.
The Stars in juſt ſuch Chryſtal Spheres,
Have burnt above Five Thouſand Years;
They fear no Storms by Day or Night,
But thus hang Wind and Weather tight
And ſo they'l hang till Day of Doom,
By that time they'l their Oyl conſume:
And then their Glaſſes breaking round us,
In Flames they'l fall, and ſo confound us.
Nay, we can prove the *Milky-Way*,
(For all Sir *Sydrophel* can ſay)
Is but a Street of ſome ſuch Lights,
To guide the Heav'nly Folks a nights.
The Council-Chamber up above,
Is hung with ſuch; and *Jove*'s Alcove.
The Sacred *Ram* can't furniſh Horn,
For all the Lights that there are ſhown:
Horners they've none, and I dare ſwear,
There's ne're a *Tallow Chandler* there.
Prometheus once (that Son of Fame)
Upon a Viſit hither came;
And lik'd the thing ſo wondrous well,
He ſtraight upon the Tryal fell: But

But whether (as ſome Authors ſay)
The *Tallow-Chandlers* ſhew'd foul play,
Or Link-boys us'd to break his Glaſſes,
(For variouſly the Story paſſes)
The Project fail'd, and he run mad,
Such Luck the *Virtuoſo* had,
That's all the Bird, the Poets ſay
Lies gnawing of him Night and Day.
May more propitious Fates attend
Our preſent Art-improving Friend!
Were this Deſign but underſtood,
'Twould be of Univerſal good;
The Stars they might to ſleep a-nights,
And leave their work to theſe NEW LIGHTS:
The Midwife-Moon might mind her Calling,
And noiſy Light-man leave his bawling:
Men may pull in their Horns, and be
From *Officers* and *Summons* free.
Nay with ſuch potent influence
Their ſtreaming Rays they do diſpence,
That if the Sun ſhou'd lie too long,
Here he might have his Buſineſs done:
He might indulge in *Thetis* Lap,
And while theſe burn, take t'other Nap.
Oh! had you been the other Night
In *Cheap-ſide* at the amazing Sight,
Where with their Sawcer-eyes they hung,
And gather'd the admiring Throng;
The Scatt'ring Light got all the gaudy way,
Some People roſe, and thought it day.
The plying Punks crept into holes,
Who walk'd the Streets before by ſholes;
The Night cou'd now no longer skreen
The Tavern-Sots from being ſeen.
The Light-men, they, began to rally,
Who bluſh'd, and ſneak'd down *Grocers-Alley*.
The Tempeſt you have ſeen, no doubt;
Juſt ſo the Candles all went out,
Thoſe ſilly Tools no more cou'd burn
Than Kitchin-Fires before the Sun.
The Quaker with up-lifted hands,
By *Yea* and *Nay* the Rogue commends;
Of all their boaſted LIGHTS, he ſaid,
Theſe never enter'd once their head.
When we compare our Times with thoſe are paſt,
We cry, This Age of greater LIGHT can boaſt;
I'll ſay ſo too, if this INVENTION hit,
Elſe ſwear, Our Age wants Wit as well as Light.

Licenſed and Entred according to Order.

LONDON: Printed by *R. Roberts*, for *William Rogers*, at the *Sun* over-againſt St. *Dunſtan's* Church in *Fleetſtreet*. MDCXCI.

Fig. 7.—Doggerel on new street lamps.

was for lighting during the forepart of moonless nights in winter. At about this time, in an effort to compel compliance of citizens with lighting regulations, contractors were authorized to provide certain street lights at stated prices, the cost of such service to be levied upon delinquent householders.

About 1691 new and improved oil lanterns appear to have been installed. The accompanying doggerel, written by an amazed and gratified observer, bears that date.

Ralph Thoresby's diary as of 1712 contains this allusion—"All the way, quite through Hyde Park to the Queen's Palace at Kensington, lanterns were placed for illuminating the roads on dark nights."

The following account of street lighting conditions in London during the eighteenth century is taken from Chamber's Book of Days, published in 1864.

"The rude character of these illuminations may be seen in Hogarth's view of St. James Street where the best would naturally be placed. Fig. A of the following group is copied from this view, forming the background of the fourth plate of the 'Rake's Progress' (1735). A rough wooden post about eight feet high is stuck in the ground; from this stretches an iron rod and ring, forming a socket for the annular lamp, dimly lighted by a cotton wick floating in a small pan of oil."

"Globular lamps were the invention of one Michael Cole, who obtained a patent for them in 1708, and first exhibited one of them the year following at the door of the St. James Coffee House. He described it as a new kind of light, composed of one entire glass of globular shape, with a lamp which will give a clearer and more certain light from all parts thereof, without any dark shadows or what else may be confounding or troublesome to the sight, than any other lamps that have hitherto been in use. Cole was an Irish gentleman, and his lamp seems to have won favor; it slowly, but surely, came into general use and is shown in our Fig. B."

"It was customary in the Hogarthian era, and until the close of the last century, to bestow much cost on the iron-work about aristocratic houses. The lamp-irons at the doors were often of highly enriched design of wrought metal; many old and curious specimens still remain in the older streets and squares of our metropolis. Fig. C depicts one of these in Manchester Square, and the reader will observe the trumpet shaped implement D attached midway. This is an extinguisher and its use was to put out the flambeau carried lighted by the footman at the back of the carriage during the night progress in the street. We give a second and more ornate example of a doorway lamp and extinguisher from Grosvenor Square, and it may be remarked as a curious instance

of aristocratic self-sufficiency, that this spot, and a few others inhabited by the nobility were the last to adopt the gas lamp. It was not until 1842 that gas was permitted to shed its rays over the genteel gloom of this neighborhood."

In 1736 there were about one thousand lamps in the streets of London. In that year the lighting was taken out of the hands of citizens and was reorganized. The number of lamps was increased to 4679, and in 1738 to about 15000. At about this time oil lamps were installed extensively. In 1762 oil replaced other illuminants quite generally and thereafter it continued to be the leading illuminant until the beginning of the nineteenth century.

Street lighting became a regular function among the principal cities of Europe during the latter part of the eighteenth century. By 1786 it had been adopted systematically not only in London and Paris but also in Vienna, Amsterdam, Madrid, etc.

EARLY AMERICAN PRACTICE.

Ideas and materials of illumination in America were derived inevitably from European sources. They were adapted, however, to the cruder modes of living and were modified by differences in natural conditions. From the earliest settlements to the eighteenth century pine knots ("candle wood") were employed largely as sources of light. These were supplemented by tallow dips, rushlights, etc. Tallow, however, was scarce and wax was expensive. Dips were formed from any grease which was available while all sorts of fibres served as wicks.

The latter part of the seventeenth century witnessed the beginning of the whale industry which by 1715 developed into one of the great industries of New England. In consequence, crude whale oil became the principal source of light in the colonies, especially in New England. About the middle of the eighteenth century spermaceti candles were manufactured in large quantities. Whale oil was finally improved by a refining process and continued to play an important part in American lighting until displaced by gas and mineral oil during the nineteenth century.

The discovery of oil in Pennsylvania in 1859 resulted in the rapid introduction of kerosene, a simple and reliable source of light which is still used largely in rural districts.

19a

OLD STREET LAMPS.   ARISTOCRATIC EXTINGUISHERS.

Figs. 8. & 9. Old London Lamps and Lamp Posts.[4]

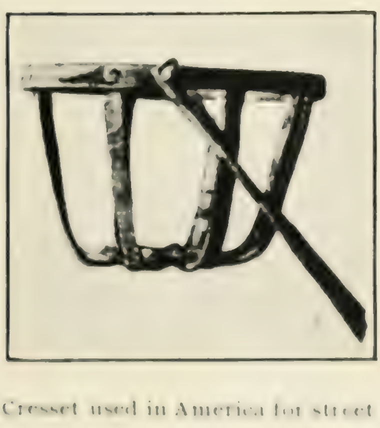


Fig. 10. Cresset used in America for street lighting.[5]

Street lighting followed the lines of European development, tending however toward the more general use of those sources of light which have just been referred to as most readily available in America. "There were as early as 1695 several large iron cressets or fire baskets on the corners of some of the more frequented streets (of Boston). These were kept supplied with pine knots by the watchman." The first organized street lighting under municipal auspices is recorded as follows: "In 1697 the streets of New York were first lighted. At every seventh house a pole was projected on which was hung a lantern. When there was a 'light moon' candles were not lighted in the lanterns."[5]

In Newport about 1751 "street lamps were hung out of shop windows and houses and this was due to private enterprise. In 1751 the town petitioned the General Assembly of Rhode Island to pass a law for the protection of these lamps as wilful and malicious persons would often break them. After setting forth the public spirit and enterprise of the inhabitants of Newport in establishing 'at their own cost and charge a number of glass lamps and fixed them to the outside of their houses, shops, etc., to the great advantage of said town in lighting the streets in the night season' it provided for the encouragement of a similar spirit in others, and for the punishment of 'wilfully and maliciously breaking one a penalty of twenty lashes or a fine of not less than twenty pounds, old tenor, to be imposed on every person convicted of this misdemeanor'."[7]

The first public street lamp posts were installed in New York City in 1762. These were of wood and were erected and maintained at the expense of the city. They supported oil lamps which remained in service until the introduction of gas.

"The lighting of oil lamps involved the use of a ladder, a vessel of spirits of turpentine, a lantern and a torch and if by the severity of the weather the torch was extinguished the relighting of it, before friction or 'locofoco' matches were known, was a dilatory matter."[9]

In 1772, through private enterprise in Boston, a committee, of which John Hancock was a member, was appointed to secure from England three or four hundred street lanterns—"lamps suitable for properly lighting ye streets and lanes of this town."

A large number of these were lighted for the first time on March 2nd, 1774.[6] This marked the real beginning of street lighting in that city although for a number of years previously there had been a certain amount of lighting due to lanterns at front doors or gates of the larger residences. Not until 1792 did the city of Boston undertake street lighting as a public service.

In Brooklyn, in 1800, owing to increase of vice and crime on the streets at night householders were recommended "to put candles in their front windows on dark nights as a convenience to those having to be upon the streets, and that was the genesis of street lighting in Brooklyn."[8]

The following is a statement obtained by the author from Dr. Walter Hough, Curator of Ethnology, United States National Museum. "Such information as has been collected shows that up to the discovery of gas, American street lighting was a replica of that of Europe, that is, lanterns hung out from stores, taverns, etc., fed by private enterprise. Mostly the streets were unlighted. In more advanced cities the corners were lighted, the lanthorns being attended by the city lamplighter, and this system was gradually extended. Gas has been in use for over one hundred years, and with its introduction civic lighting made great progress. In small towns, however, the streets remained dark until petroleum was discovered, when lampposts became a feature."

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EARLY STREET LIGHTING BY GAS.

The opening of the nineteenth century witnessed the beginning of gas lighting. Although for one hundred years previously it had been known that an inflammable gas could be obtained by distillation of coal, William Murdock is generally credited with

being the first to demonstrate the feasibility of employing such gas on a large scale for illuminating purposes. In 1792 he lighted his house experimentally, and in 1802, in celebration of the Peace of Amiens, he lighted with gas the front of a manufactory in Soho, near Birmingham, England. Meanwhile Philippe Lebon in Paris had experimented with gas obtained from wood and other-

Fig. 11.—Early use of gas in street lighting.

wise. He also had demonstrated the practicability of gas lighting. F. A. Winsor of Germany, probably obtaining his first knowledge of the subject from Lebon, likewise developed a gas lighting system. Winsor came to London in 1803 and, proving himself a vigorous promoter, early succeeded in organizing a company to do gas lighting. He receives credit for the first

street lighting by gas.. In 1807, as a demonstration, he lighted a part of one side of Pall Mall, the gas being conveyed through lead pipes. The accompanying cut, reproduced from a publication of the South Metropolitan Gas Company of London, shows an early equipment in Pall Mall. It is stated that each such cluster of lamps "consumed about 20 cu. ft. of gas and gave a lighting value of about 30 candles."

The "cockspur" burner here illustrated consisted of a tube having three perforations. It was followed shortly by the "cockscomb" burner. Then came the slit tube producing the "batswing" flame. About 1820 the "fishtail" or union jet burner was developed. About 1853 the pre-heated air principle was announced, giving rise to many regenerative burners during the next thirty years.

The first real municipal street lighting by gas was put into operation in St. Margeret's Parish, Westminster, April 1st, 1814. Gas lamps were first used in street lighting in Paris in 1818. During the next two decades gas was adopted in most of the principal cities of Europe.

Gas lighting was introduced in America at Baltimore in 1816. The first street lamps were placed in operation early in 1817.[19] In 1825 gas mains of wooden logs were laid along Broadway, New York, from the Battery to Canal Street. In 1827 the first gas street lamps were placed in service and iron posts replaced wooden ones.[17] On January 1st, 1829, the first Boston street gas lamps were lighted in Dock Square. The first Philadelphia lamps were placed in service in 1835-36. Thenceforth, gas companies began operations in most of the larger cities and towns, and gas rapidly displaced oil for street lighting.

Developments of the next few years having a bearing upon street lighting practise include the regenerative burner previously mentioned. In 1855 the Bunsen burner was invented. In 1858 or 1859 the moonlight schedule was abandoned in New York City. About 1875 the Lowe process water gas was perfected. About 1885 Welsbach produced the first successful gas mantles which were further improved during the next eight years.

The inverted burner gas mantle lamp made its appearance about 1902. Experiments with high pressure gas lighting were begun in Europe in 1897, resulting in successful systems in 1904.

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THE DEVELOPMENT OF ELECTRIC LAMPS.[24 25 26]

EARLY STREET LIGHTING BY ELECTRICITY.

Sir Humphrey Davy, in 1808, produced the electric arc which is commonly considered to have been the forerunner of the arc lamp. He used charcoal electrodes supplied with current from Volta's primary battery or "chemical generator." Davy repeated the experiment before the Royal Institution in London in 1810. In his own words—

> "When horizontal pieces of charcoal, about an inch long and one-sixth of an inch in diameter, were brought near each other, within a thirtieth or fortieth part of an inch, a bright spark was produced, and more than half the volume of charcoal became ignited to whiteness; and by withdrawing the points from each other a constant discharge took place through the heated air, in a space equal to at least four inches, producing a most brilliant ascending arch of light."

The discovery of induced currents (Faraday, 1831) led to the establishment of the connection between electricity and magnetism and thus to the magneto-electric machine. This, equipped with the commutator (Ampere, 1832), provided a supply of direct current with which the arc was studied experimentally during the next few decades. In 1843 Foucault improved upon Davy's charcoal electrodes by employing graphite pencils made from carbon deposited upon the sides of gas retorts. In 1845 the electromagnet was invented by Wheatstone and by Cooke. This led to

the dynamo-electric machine, announced in the same year by Wheatstone and by Siemens, having electro-magnets instead of permanent steel magnets as in the magneto-electric machine. This apparatus was brought to the stage of practicability by Gramme and others in 1870. There resulted an increase in arc experimentation.

A regulating device to feed the carbons and maintain the arc was regarded by most investigators as essential to success of the arc lamp. Jablochkoff, however, as if to prove the rule by an exception, invented a lamp without a regulator and this lamp was the first to attain commercial success in street lighting in Europe. Jablochkoff's lamp,[21] which became known as the "electric candle", consisted of two thin vertical strips of carbon bound closely together and separated by insulating material. The exposed ends were bridged by fine carbon which served to start the arc when the current was first applied. A number of these "candles" were placed in an opal globe, usually four in a twenty-inch globe. Each lasted about one and one half hours, at the expiration of which time the current was switched to another "candle." Alternating current was employed to equalize the rate of consumption of the two strips.

During the Universal Exhibition in Paris in 1878 the Place and Avenue de l'Opera were lighted by Jablochkoff candles. While this may not have been the first use of electric lamps for street lighting it was the first notable installation. Professor Sillinan wrote from Paris under date of July 27th, 1878, about "the splendor of the electrical illumination. The effect is magnificent and at this moment there exists nothing in this city of splendid effects to compare with this magical scene. The vista is about two thirds of a mile and the effect incomparably finer than any show of artificial illumination ever before seen."

The candle power of these lamps is stated in various records as anywhere from 285 to 1500. It is probable that the actual value was of the order of the smaller of these figures.

The Jablochkoff electric candle was especially interesting because it offered a possibility of the much sought means of "subdividing the electric light." It was costly and unreliable, however. While attaining some commercial success on the continent

Fig. 12.—Parisian street lighting by Jablochkoff candles.

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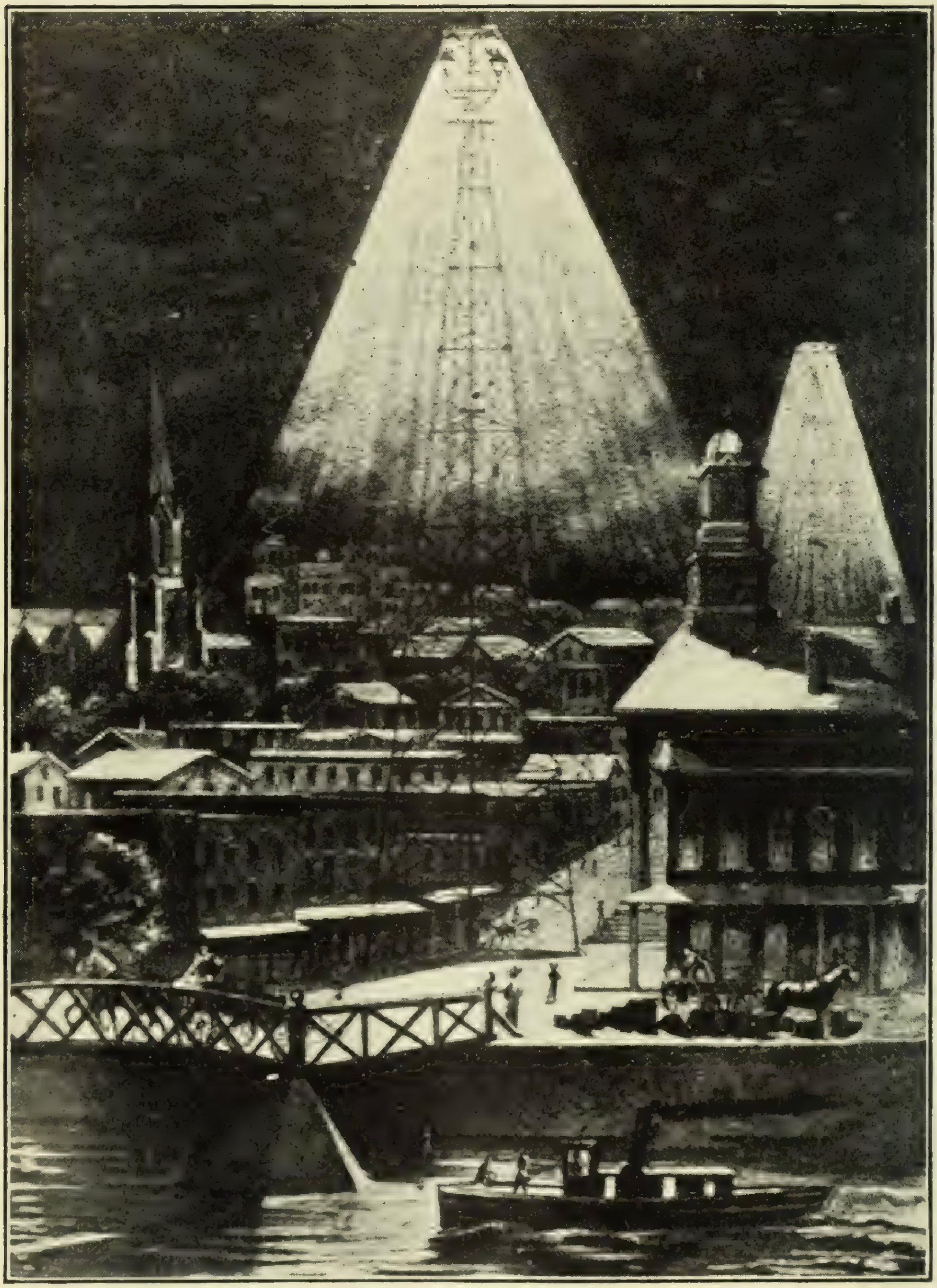

Fig. 13.—Early electric light towers.

it hardly progressed farther than the trial stage in England and made no progress commercially in America.

In America the work of Brush, Thomson, Houston, Weston, Wood and others provided superior arc lighting systems which became available shortly after the introduction of Jablochkoff candles in Europe and which endured for two decades. Brush[22, 27] in 1876 completed his first dynamo-electric machine. In 1877 two of his dynamos with a simple regulating type of arc lamp were tested at the Franklin Institute in Philadelphia. In 1878 he invented the series arc lamp with regulating shunt coil and in 1879 developed the double carbon "all night burning" lamp.

The first public street lighting by arc lamps in this country was inaugurated in April 1879 when twelve arc lamps were placed in service in the Public Square in Cleveland. Probably the most important early street lighting installation was in New York City. Beginning with December 20, 1880, Broadway was illuminated by arc lamps from Fourteenth to Twenty-sixth Street. By the end of 1881 arc lamp stations were in operation in several of the larger cities of the country.

The first series machine of the Brush company was designed for six lights. This was followed by sixteen light machines. In 1880 forty light machines were produced. By the end of that year about six thousand Brush lamps had been installed. Later sixty-five light machines were built and finally one hundred and twenty-five light machines were standardized.

The strong concentration of the light from the open arc lamp in a zone about forty-five degrees above the nadir led to the use in some localities of towers for supporting the lamps at a relatively great height. Probably the exaggerated ideas which prevailed concerning the power of the arc lamps led to comparison with the moon or even with the sun. The step from this to the idea of high mounting was natural. These towers may still be seen in the middle west. They are usually from 125 to 150 feet high, and mount from four to eight lamps. The early towers in Elgin were perhaps typical. There was a main central tower 150 feet high surrounded by six towers each 125 feet high and located about one-half mile apart. These furnished the principal public illumination for a population of 16000 in an area of about four square miles.

Electric light towers[23] were installed in Akron in 1881. One is described as an iron mast 207 feet high held erect by iron cable guys. The lamps were lowered by machinery. Another notable installation was at San José, Cal., where a gas pipe structure was erected in 1882 over a street intersection the base resting upon the four corners. This tower was 200 feet high and mounted four "4000 candle power" lamps equipped with a reflector.

The further development of electric street illuminants is of recent occurrence. The enclosed carbon arc lamp was perfected about 1894.[28] The magnetite lamp about 1904.[29] The long-burning flame arc lamp a little later.

Of the incandescent lamps the carbon series type was never satisfactory. The metalized carbon[30] (Gem) series lamp was but little better. The tungsten filament lamp was the first series lamp to offer really acceptable service. The Gas filled Mazda lamp is very satisfactory and has invaded successfully the street lighting field so long occupied by the arc lamp as the only high power illuminant.

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SEARCHLIGHTS IN THE A. E. F.*

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Until about the beginning of 1918 the American army had no searchlights in France except a few elevated mast, limber and caisson, horse-drawn outfits, which were a poor imitation of earlier German apparatus. While that equipment might have been useful in the old open warfare, it could not be used in the World War.

Early in the history of the war it was thought by some that the army searchlight would have many uses on the battlefield, among which were the following:

"To discover and keep in touch with the movements of the enemy during the night.

"To seek out and illuminate hostile objectives, so as to fire upon them.

"To blind the enemy.

"To illuminate roads and possible hostile positions in the more distant foreground periodically by the light.

"To search the near foreground.

"To support fire effect by illumination of hostile targets.

"To disturb hostile works by alternate blinding and turning on the beam or by working the beam back and forth.

"To blind opposing searchlights.

"To support attacks in the foreground by throwing the beam in front of the advancing troops and screening their movements.

"To reveal obstacles to their own artillery, which is thus enabled to destroy the obstacles.

"To blind the enemy and disturb his forward march and firing capacity and confuse him by making him think his plans are discovered.

"To facilitate the landing of aviators at night.

"For anti-aircraft work and night bombing defence."

* Paper presented at meeting of New York Section in New York City on April 8th, 1920.

Of these uses for the searchlight, none but the last was of importance in the past war.

The searchlight was not used to discover and keep in touch with the movements of the enemy during the night. Such an attempt would have only meant the discovery of the location of the searchlight and its destruction very soon after the first exposure of the beam. Verry lights or star shells were used with success for this illumination.

Any hostile objective which could have been illuminated by the searchlight, could have been located much more accurately by the usual methods during the day before the night it was to be fired upon.

The blinding effect of a searchlight beam is of so little importance that it is not known that this use was ever tried. The writer was in an aeroplane at an altitude between two and three kilometers on a dark night and was illuminated by two 90 cm. Harle projectors, with golden mirrors, which were emplaced about three kilometers apart and observed no blinding effect of any importance. One could look directly into the light without hurting the eyes, but nothing could be seen on the ground within a radius of about 100 meters from the light. Outside this area, however, a white road and some dark trees could be distinguished. On moonlight nights, even when the aeroplane was maneouvered so that the beams would at times illuminate the tops of the wings, the supposed blinding effect of the searchlight was not apparent to the writer.

The searchlight was not used to illuminate roads and possible hostile positions in the more distant foreground, nor to search the near foreground, nor to support fire effect, nor to distinguish hostile works, nor to reveal obstacles, for reasons given above.

The searchlight was not used to blind opposing searchlights nor the enemy in his forward march, for reasons already given. Opposing searchlights were at least five to eight kilometers apart. A raiding party would drop out of sight as soon as any light was made, and a general attack was always preceded by a barrage.

Two small searchlights were used at the Third Aviation Instruction Center, near Issoudun, to facilitate landing at night while the first American night chase squadron finished its training in this very important branch of the aviation work. Two

larger lights which had been used on the front were used to illuminate the avion in the air. As the training of night pilots, with searchlights co-operating, was not begun in France by the American army until the night of Nov. 10, 1918, it is a lamentable fact that American trained night squadrons were not used in checking the numerous German bombing aeroplanes which crossed the lines at night.

The searchlights, which were used in the American, British, and French armies, were used for anti-aircraft work on the fronts and to assist in the defense of cities against night bombing.

The first American searchlight troops in France, under Lt. Col. John C. Gotwals, commanding the 56th Engineers, A. E. F., had their first headquarters at the Fortresse du Mont-Valerien, at Suresnes, near Paris, which was the depot of the French projector service.

Some preliminary training was received from the French and then a few of the troops saw their first actual operations on the British front in Flanders and on the French front in the Somme defensive. As the Americans had no suitable equipment of their own they were mixed with the searchlight crews of the other armies at first and so had the benefit of learning the equipment and methods used by the other nations.

During the early part of 1918, Major Lewis, son of the machine gun inventor, was away from the regiment for some months, having returned to the United States to guide the design and production of suitable searchlight equipment. His work in the U. S., before his return to France, made possible the development in this country of the best field searchlight equipment in the world.

When the French moved their searchlight depot to Chartres, the Mont-Valerien became our Temporary Searchlight Depot. This location was advisable because the apparatus with which we were to be equipped was to be produced in Paris. Outside the fort and on the flats, near the Docks of Rueil, a small training area was established. It was here that many of the first companies received their "behind the lines" training because it was nearer the fronts where they were to operate than was the American Anti-Aircraft Searchlight School, which had been started shortly before at Champigny, near Langres (Haute Marne). It

was on these flats that the 56th Engineers later assisted in the defense of Paris.

The worst bombing raid on Paris was on the night of March 13, 1918. There were more German aeroplanes overhead and larger bombs dropped than either before or after that date. At that time the searchlights were not permitted to expose near Paris. On the 21st of March the Big Bertha started to drop shells into Paris. On April 5, 1918, Paris was included in the Zone of Advance. The use of searchlights on the defense of Paris extended from about that time until the last raid shortly before the armistice. In the early part of May the writer was made commanding officer of "A" Company; and on the 15th of that month the 1st and 4th Platoons moved to the French front.

The headquarters of the 56th Engineers was afterward moved to Colombey-les-Belle, which was nearer the later activity and close to the American front. Two companies of the regiment operated in the St. Mihiel Drive.

About the middle of June, 1918, a detachment consisting of the 21st Platoon, was ordered to the French "Centre de Instruction de D. C. A.," at Longuerperte, near Pont-sur-Seine, not far from Provins, which was the French general headquarters. This little village, which will be shown in Fig. 1, was the headquarters for the area where the French searchlight troops received three weeks special training before going into action. There was a French aviation field not far away at the little town of Pars. In the manoeuvers, an aeroplane would co-operate by flying over at the altitude usually traveled by the bombers.

On June 23, 1918, two bombs were dropped near the British rest camp at St. Loup, which was about three kilometers back of Longuerperte. On that night the one American searchlight then at that place caught the aeroplane in its beam before one of the thirty-three French lights ready for operation could make a target. This was the first training in France where an aeroplane was used for the practice of the American searchlight.

On July 15th a French infantry outfit came through on its way back to a rest camp; officers still wearing soldiers uniforms. That night bombs were dropped on a prison camp nearby, at Romilly. It was said that fifty Germans were killed and one hundred wounded. This is mentioned to give some idea of the

practical training conditions. All the training of the American searchlights was done in the Zone of Advance.

On the night of September 16, 1918, a Voisin bomber was attacked by a Spad and a Brueguet while the bomber was held in the beams from the searchlights. This was the first night combat in the beam of an American searchlight in France.

When the Sperry-G. E. Type searchlights (large base) began to arrive in France, the American Searchlight Depot was opened at Gievres. This was the location of the American Engineer Depot, which was the largest engineer dump in the world.

Something like 130 searchlights were in use by the 56th Engineers before the armistice, one of these being the so-called dishpan type, first conceived by Major Lewis, and now the highest development in field searchlights.

On his way home, about two months after the armistice, the writer saw some of the Mack power plant outfits in their crates just as they had been unloaded at Brest.

EQUIPMENT.

The first practical searchlight equipment secured by the American troops in France consisted of six 90 cm. Sauter-Harlé projectors with automatic arc control and metallic reflectors. They were mounted on four rubber tired wheels and arranged to be transported on light Brasier trucks. The mirror was of bronze, plated with gold and nickel, and reflecting a yellowish light which was better than white beams on nights when there was moisture in the air. An extension had been added to the front of the chassis of the truck and a generator attached to the automobile engine by means of a flexible coupling. The generator had sufficient capacity to produce an arc of 130 amperes at 55 volts, which was found to produce the best beam. The French had a rule by which they used a current so that the number of amperes was equal to the diameter of the reflector in centimeters, with the result that the arc in the smaller projectors was not as hot as it might have been.

The use of these outfits was being discontinued in the French army. Before we used them the yoke supporting the journals had to be lengthened so that the light could be plunged; that is, turned through the vertical angle through the zenith and down

on the other side. This movement is absolutely necessary if the searchlight is to be used successfully against the aeroplane. We also added a distant control modeled after the British pipe control, but with the improvement of a worm reduction gear at the end of the pipe with the handwheels. This reduction reduced the tendency to search too rapidly, and was made standard for all lights.

Fig. 2 shows an emplacement containing the Harlé projector equipped as described above. A circular iron track, made up of removable sections, carried half the weight of the control and provided an azimuth scale for the searchlight, on the other side of the searchlight emplacement and at the right is the sound direction indicating paraboloid for locating the enemy aircraft in the dark. On the left is a thatched roof covering a pit which contained the plotting board for making corrections for sound time lag. The tin can which may be seen suspended from the thatch, shades an electric light which was supplied with current by means of a small branch taken from the main leads to the searchlight. These leads may be seen in the foreground. They come from the Brazier power plant which is shown in its emplacement in Fig. 3.

Except for the six searchlights referred to above, and one British Siemens projector which we equipped with a Sperry lamp, and about eight of the Sperry-G. E. Type (large base) remodeled searchlights which were in use only shortly before the armistice, the equipment of the regiment consisted almost wholly of B. B. T. 90 cm. projectors, with silvered glass mirrors and lamps with the simplest automatic arc control known.

The generators were purchased from a Paris manufacturer and mounted on remodeled American trucks which had been intended for transport service. At least three different makes were used for this purpose.

The power plant equipment, such as used by most of the platoons, consisted of a Riker, 3 ton, or other available truck, from which the transport body had been removed. A channel iron extension was added at the front so that a cradle was formed for a shunt wound, four pole, direct current generator, which was driven by the vehicle motor through a flexible coupling.

On the dash was mounted a switchboard containing the main switch, circuit breaker, voltmeter, and ammeter. The seating

capacity was for six soldiers; the driver and two others on one seat, and three more facing the rear, there being a narrow tool box separating the backs of the two seats.

Under the rear seat was a reel of 100 or 200 meters of double conductor, leather covered cable, provided at each end with polarity connectors for attaching to the switchboard leads and to the searchlight. Cranks were provided at either end of the reel for winding up the cable.

A small drum with steel cable was provided for drawing the searchlight up a pair of rails which were placed from the rear of the truck to the ground. When the light was in position for transportation it was locked in place by means of a few simple levers and two wing-nuts so that much of the weight was taken off the wheels.

Mud guards were built over and around the rear wheels of the truck and boxes provided for supplies and mounted on the running boards and slung under the rear.

The B. B. T. searchlight was provided with an ammeter and voltmeter in one case, and with a disconnecting switch, which could be opened in the event of trouble with the arc, thus making it unnecessary to signal to the switchboard before working on the lamp. This searchlight was of course equipped with the extended trunnion pipe control.

Fig. 4 shows the 90 cm. B. B. T. searchlight in a typical emplacement, which was one in the writer's command on the western front. Here the paraboloid is shown locating an aeroplane. The searchlight shutter is closed; corrections are being made by the soldier working at the plotting board.

The first make-shift distant control used with the 150 cm. Sperry-G. E. Type searchlight in France was devised by the writer and had a control pipe attached to the shaft of the pinion which engages the circular track fixed to the hood of the light. In Fig. 5 may be seen the searchlight as it was received from the United States, while Fig. 6 shows the control as added with the old azimith control wheel mounted at the end of the pipe where it was used to produce the elevation movement. The rack was rotated and fixed in a position so that the light might be plunged through the zenith.

With a light greater than 90 cm. in diameter there was needed a large gear reduction between the control pipe and the hood as the large inertia effect would have otherwise caused the beam to lag or lead the control in starting or stopping the elevation movement by tending to twist the pipe.

Fig. 7 shows a simplified diagram of the Sauter-Harlé lamp circuits. In this lamp the regulation was effected by means of a

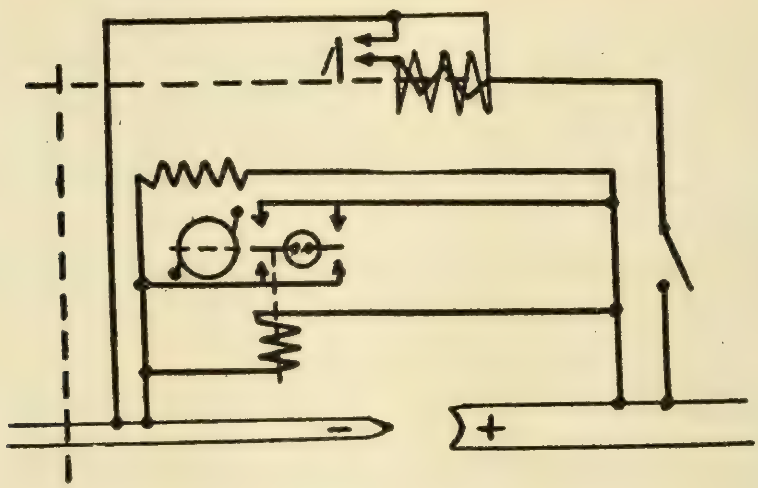

Fig. 7.—Diagram of the Saute.-Harlé lamp circuits.

small shunt wound motor, the armature of which received current first in one direction and then the other as determined by the action of a relay influenced by the voltage of the arc. The automatic control could be operated or disconnected at will, or at any time aided by hand control.

The mechanism contained a solenoid arrangement for striking the arc. The circuit of the solinoid was through a switch on the positive side of the line, through the coils, and to the negative side of the line. The inner coil gave the initial strong impulse to its armature whch opened the shont thus placing the high resistance coil in series with the first. The solenoid armature struck the arc by acting through a lever on the feed screw of the negative carbon holder.

When the armature of the reversing relay was lifted current flowed through the motor armature so that the direction of rotation caused the carbons to move together; then when the relay was dropped the motor was reversed and the carbons separated.

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Fig. 1.—French searchlight troops, headquarters training.

Fig. 2.—Emplacement containing Harlé projector.

Fig. 3.—Brazier power plant in emplacement.

Fig. 4.—[illegible] cm. B. B. T. searchlight in a typical emplacement

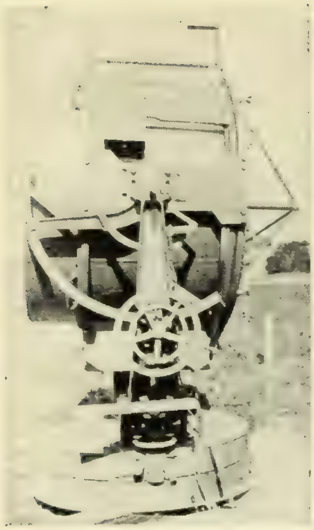


Fig. 5.—Searchlight as it was received.

Fig. 6.—Searchlight with control modified.

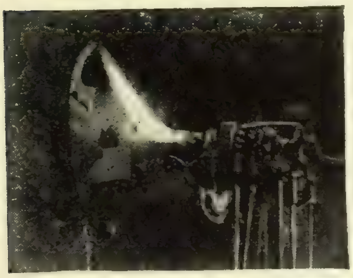
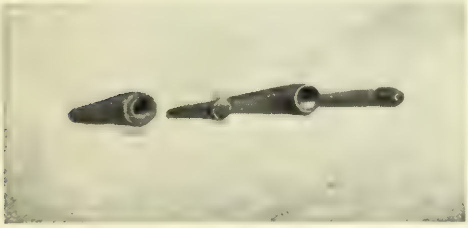


Fig. 9.—Arc with the Sperry carbons.

Fig. 10.—Arc with experimental carbons.



Figs. 11. and 12.—Comparison of used carbons.

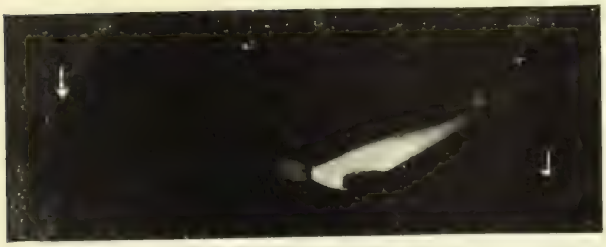


Fig. 13.—Sperry carbon in Harlé 90 cm. projector.

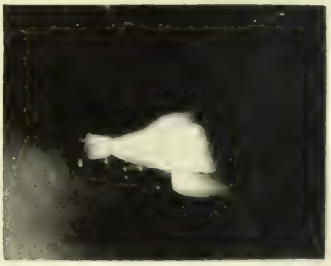


Fig. 14.—Normal arc Harlé 90 cm projector.

The relay was operated by the change of strength of current in the coil produced by the changing resistance of the arc due to its change of length. The length of the arc was determined by the adjustment of a spring resisting the pull of the relay coil.

The B. B. T. lamp control was much more simple and the oscillation of the carbon not so great as in the Harlé. A simplified diagram is shown in Fig. 8. In this lamp the arc was struck by the regulating motor which only operated in one direction. Movement in the other direction was produced by a clock spring which always opposed the rotation of the motor.

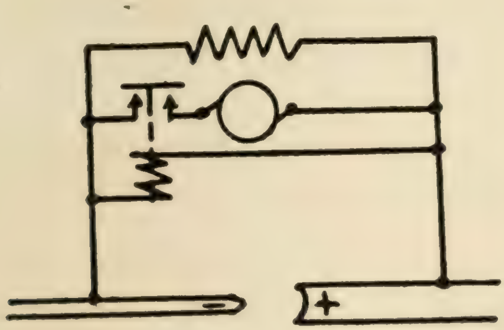


Fig. 8.—Diagram B. B. T. lamp circuits.

The Sperry lamp was not so simple. The few lamps of this type, which some of our best men operated in the training area, soon demonstrated that the thermostat control was too delicate for field use. Even with the greatest care the thermostat could not be kept in order. The occulter was frequently burned so that the use of the lamps in the burned condition at the front might have been fatal.

As there were always two men at the light during operations there was no need for automatic control. Even with the B. B. T. lamp the arc was usually held by hand.

Field equipment must be moved rapidly over rough ground and in the dark. It must be emplaced, and a change of location is frequently made. Laboratory methods of operation and maintenance cannot be used in the field.

Clips were fixed inside all searchlights to hold the pair of carbons next to be used, so that they would be dry and ready for use when the time came.

In the event of the destruction of all the carbons at one emplacement, others would have had to have been secured from a nearby searchlight. As the French projectors and the Sperry searchlights might have been located near each other in the field it was desired to know if the carbons could be interchanged, therefore some experiments were made.

The French carbons such as were used in the Harlé and B. B. T. projectors were 11 and 27.5 millimeters in diameter for the negative and positive, respectively. In the first experiment the positive carbon was turned down to 16 mm. and the pair were burned in a 150 cm. Sperry-G. E. Type searchlight, drawing 150 amperes at 75 volts. The arc was very unsteady and it seemed to travel around the lip of the crater. There was a tendency for it to move up on the metallic shields on the positive head.

Fig. 9 shows the arc with the Sperry carbons during normal operation. The experimental carbons in the same lamp are shown producing their best arc in Fig. 10. The two types of carbons were burned alternately a number of times. The arc from the Sperry carbons usually burned steadily, and that from the other carbons acted as if a strong wind were blowing it first in one direction and then another.

The French carbons became red for a greater length than did the Sperry. Of course if the negative carbon had been copper plated, as was the Sperry negative, it would have been a better conductor and less heating would have resulted. Although the negative head support became hotter than did the positive at points half way down to the mechanism box, the positive head was more affected by the heat than was the negative.

Observing the arcs through the ruby peep in the hood, the Sperry seemed to be much more nearly white than the other; it was also impossible to see the incandescent pool in the crater of the French positive carbon such as is present in the carbon made for the lamp.

Fig. 11 shows the experimental positive and negative and the Sperry positive and negative carbons, in the order named. Note the deep crater with the thick lip in the first carbon; little more than the core had been burned out. The next carbon has a very blunt nose. The Sperry carbon has a very smooth crater with

a sharp edge. Note that the Sperry negative carbon is cored and that the core is slightly burned out. A comparison of the length of the burned part of the negative carbons is made in Fig. 12. The Sperry is burned back about 2.5 cm. and the experimental, 8 cm.

As a second experiment the Sperry carbon was burned in the Harlé 90 cm. projector. The arc with this arrangement is shown in Fig. 13. Note the great length of carbon between the arc and the carbon holders. This arc was burned for 15 min., drawing 130 amperes at 55 volts, which was the usual operating power.

A much stronger light was given with the Sperry carbons than with the large ones made for this lamp, which are shown producing a normal arc in Fig. 14. The positive Sperry carbon extended about 25 cm. from the holder, and the negative the same length, but when they were removed they were straight, so little had the heat affected them.

PERSONNEL.

Ultimately the searchlight regiment commanded by Major Alexander Macomber, consisted of ten companies of 250 men each. These companies were divided into platoons of 50 men each. As each platoon operated independently they were numbered consecutively through the regiment. The geographical locations of the platoons determined their company, as five platoons covered so much area that a company commander could only visit those grouped together. For various reasons a platoon had to be moved at times to such a location as to throw it into another company.

The platoons were divided into three sections; there being three complete searchlight equipments and one sound direction indicating paraboloid to a platoon. Each platoon was commanded by a lieutenant, and each section by a crew leader who was a master engineer or a sergeant.

The crew with the searchlight and paraboloid consisted of sixteen men: crew leader, engine man, dynamo tender, lamp tender, shutter tender, pointer, telephonist, spotters (three), elevation listener, azimuth listener, elevation reader, azimuth reader, plotter, and assistant plotter.

OPERATIONS.

The diagram in Fig. 15 shows the approximate positions occupied by the pilot light crew when "standing by" or in operation. The power plant is from 100 to 200 meters from the searchlight.

At the warning "Plane Alerté" the crew was "called off" to verify the presence of all, the command was then given to "Stand By." The listeners signaled to the readers as soon as the paraboloid was directed at the sound of the bomber, the readers then started giving the angles to the plotter, who at once began to plot the course of the aeroplane. After the first three or four points had been plotted, all other readings were corrected by the assistant plotter as fast as the point is dotted on the paper.

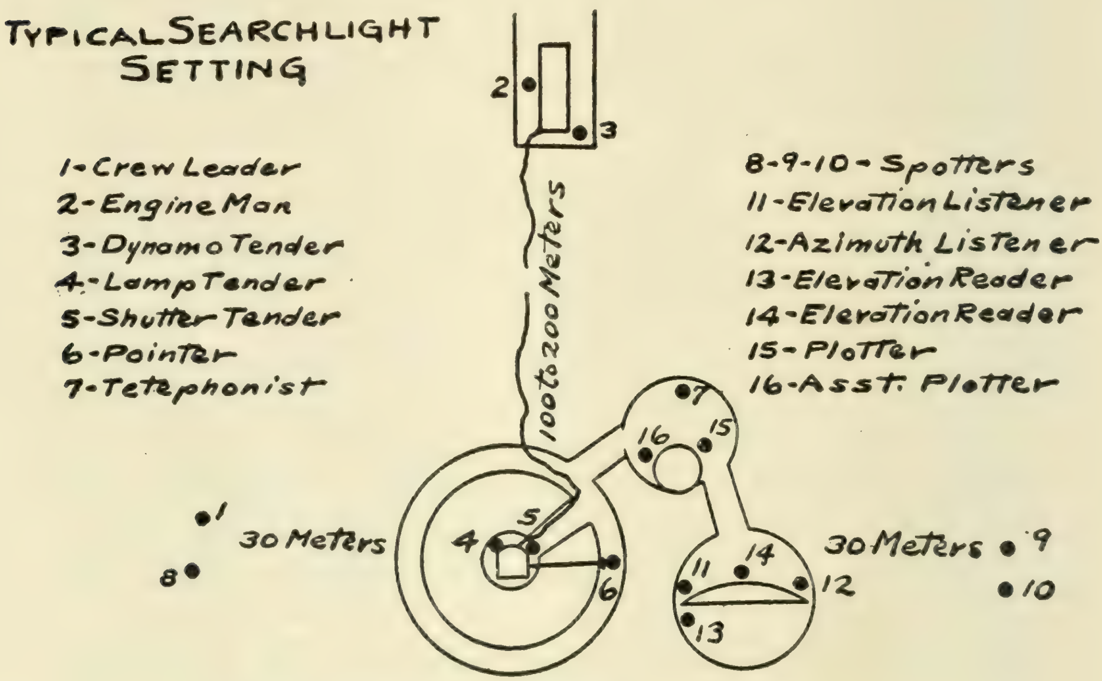


Fig. 15.—Diagram of pilot light crew "standing by"

The engine had been started at the sounding of the alerte and the arc struck in time to assure perfect operation when the aeroplane came within range.

The light pointer followed all corrected readings from the plotting board by setting his control on the elevation and azimuth corrected angles as read by the assistant plotter. At the command "Expose" the shutter tender, who was also the machine gunner, opened the light.

If the beam failed to make the target, the pointer searched very slowly in a grid formation along the general direction of flight, at the same time following the corrected readings.

In the event that a spotter located an aeroplane he took charge and directed the beam to the aeroplane. When a spotter took charge or when the beam made the target, the plotter stopped reading his corrections but continued to plot so that in the event of the aeroplane being lost, its location could be given at once.

The spotters were at first stationed at about 120 degrees apart and not less than 100 meters from the light. It was found later that more accurate work could be done by having two spotters at one place about 30 meters from the light, and the other spotter with the crew leader at a like distance on the opposite side. This change was required partly because, that while holding the aeroplane sooner when located at from 100 to 200 meters from the searchlight beam and therefore could not direct it to the target. By means of the ring sight, made by the writer and used as shown in Fig. 16, the second spotter was able to direct the beam so that it would illuminate the aeroplane without his having previously seen it. Fig. 17 shows a British overhead sight which was later tried with less satisfactory results.

Although it had been found that the spotters could see the aeroplane sooner when located at from 100 to 200 meters from the light, it was also found that the greater the distance the harder it was to guide the beam to the target. With a beam of about three degrees and the aeroplane at an altitude of between two and three kilometers, it was sometimes pretty hard to tell whether the aeroplane was above, below, to the right, or to the left of the beam unless the observer was pretty close to the light. In the dark sky there is nothing to assist the judgment of distance, direction, angle, or altitude. The spotters were required as the beam of light screened the vision of those in the emplacements, so as to prevent the aeroplane from being seen unless it was in the beam. The spotter could therefore not be too close in or too far out. He had to be as far out as possible to reduce the effects of glare, contrast, and screening, but at the same time he had to be close enough in to prevent optical illusions as to the relative locations of the aeroplane and the beam. As stated above, the writer's experience in the Zone of Advance during all eleven major operations,

demonstrated that about 30 meters was the best distance between the light and the spotter.

The single station sound ranging plotting board, for correcting the time lag angles from the directions given to the paraboloid, was developed in four months, at the end of which time the French officers in charge of the "D. C. A." told the writer that we had progressed as far as they had in four years. But we had passed them both in theory and practice some time before. A view showing the plotting board and its position for use is shown in Fig. 18. This apparatus is automatic, no special paper being needed, and no computations being required, the angles being read direct as corrected. From the desired time of 20 sec. required by our early methods, based on the practice of the artillery, corrections were being made just before the armistice by means of the apparatus shown in three seconds, which is as fast as the two sets of angles can be read.

TACTICS.

The early defense against the enemy aircraft was largely by means of anti-aircraft artillery, but it was later found that combat aeroplanes were much more effective in bringing down the bomber. Fig. 19 shows a typical vulnerable area defended by guns, and in Fig. 20 is shown the method of locating the searchlights on a typical front area when the defense was by night fighting aeroplanes. Both diagrams show the one paraboloid for the three searchlights in the platoon.

The lights were not placed closer than about 500 meters from the guns. The pilot lights had to be placed far enough away from railways, main highways, and other lines of travel, to enable accurate sound direction to be obtained. The ideal location for a light was near the crest of a hill just above the ground mists and so as to obtain a clear range of vision above 15 degrees in elevation.

When co-operating with the aviation on a front area the lights were located about as indicated: about three kilometers apart and from three to five kilometers from the lines. The searchlight equipment had to be moved up at night and kept camouflaged during the day. The searchlight was first dug in; then the annular trench for the pointer; after which the paraboloid and power equipments were emplaced.

216c

Fig. 16.—Ring sight used by second spotter.

Fig. 17.—British overhead sight.

Fig. 18.—Plotting board in position for use.

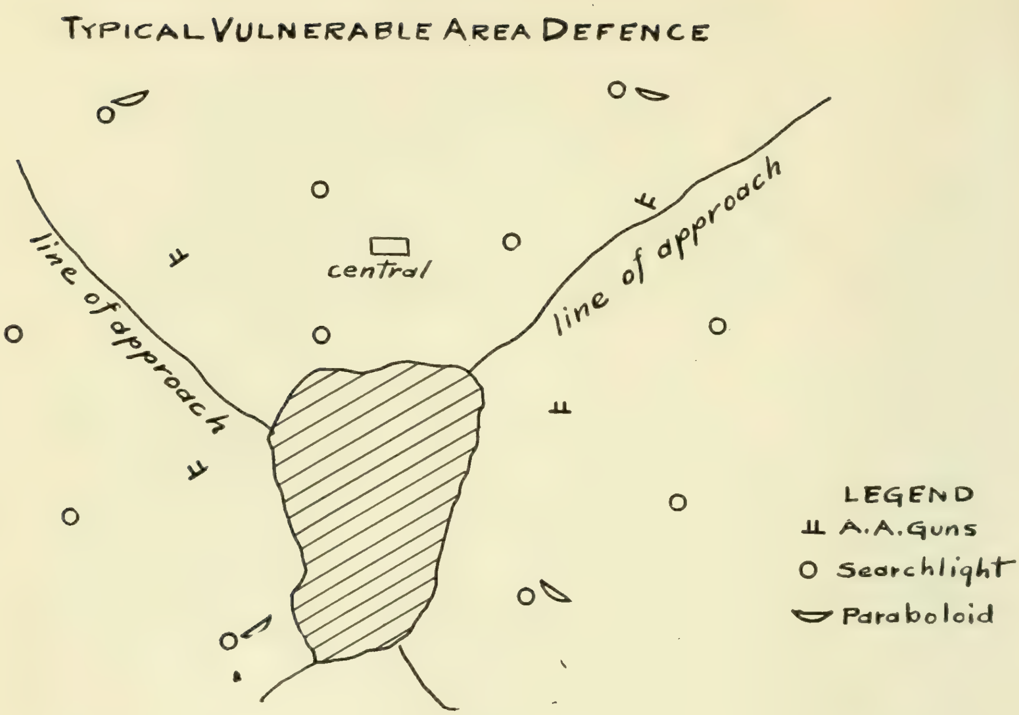

TYPICAL VULNERABLE AREA DEFENCE
central
line of approach
line of approach
LEGEND
A.A. Guns
Searchlight
Paraboloid

Fig. 19.

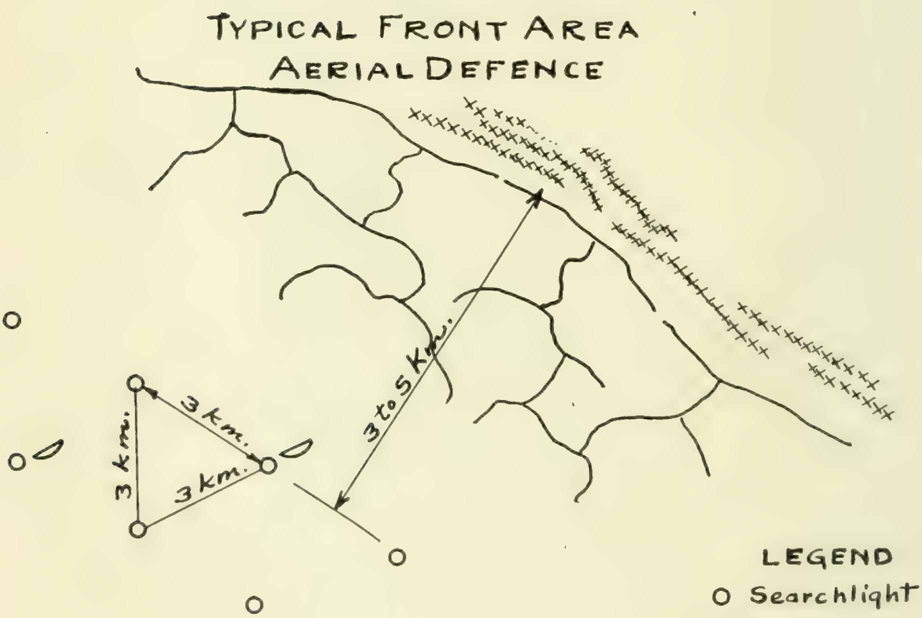

TYPICAL FRONT AREA
AERIAL DEFENCE
3 to 5 Km.
3 km.
3 km.
3 km.
LEGEND
Searchlight
Paraboloid

Fig. 20.

The pilot light which was operated at the paraboloid emplacement, indicated to the other lights the direction in which to search. When an aeroplane was illuminated it was held in at least three beams. The pilot light was in this way assisted so that its beam could leave the target and pick up the next to be located by the paraboloid.

The crossing of the beams on the enemy aeroplane indicated to the air patrol that a bomber was coming and showed its location. When a friendly aviator passed over the defended area he signaled down the color of the night or the letter of the day. When he was to attack he signaled for the guns to cease firing and the rear lights to douse. The attack was made from the rear and below; the "chaseplane" steadying down to within 100 meters behind the bomber and then creeping up slowly to about 25 meters, aiming at the under surface of the fusilage and firing one long burst. If the bomber was not surprised and opened fire first, the "combatplane" replied at once with short accurate bursts. When fired upon at close quarters the enemy usually "S'd" downward. When well inside our lines another surprise attack was tried. A knowledge of the expected moves of the aeroplanes was very important to the searchlight pointer.

The importance of aviation in defensive warfare is not sufficiently appreciated; in the future it will be any nation's best protection. But the eye with which it sees at night is the searchlight, which is therefore one of the strongest weapons for the defense of our country and our homes.

DISCUSSIONS.

Dr. Bell: It may be interesting as a mere matter of history to note that the use of the searchlight in war is strictly an American invention. I had occasion a few years ago to attempt to run down the actual story of the searchlight in war. I happen to find in one of my father's old letters (he was officer at times in charge of the heavy batteries during the siege of Fort Sumter) a reference to the use of the searchlight. The searchlight was there used for the purpose of lighting up the Fort so that the Confederates could not come up at night to reinforce it. I made a careful inquiry, conducted by Professor Holden who was librarian at West Point, and it brought out the fact that the searchlight

had not been used in the Crimean War or any of the French wars, prior to our Civil War, and so far as it appears it was first used in the Civil War at the siege of Charleston. Afterwards I found the history of that particular application, which was as follows: When the Federal troops were besieging Fort Wagner, where they were working by the old system of parallels, they brought down for lighting the enemy works the first military searchlight, which consisted of a big reflector with an oxy-hydrogen source of light. This was used in the late summer of 1863 for the first time, and after Fort Wagner was captured and the batteries were put in place for beating down the walls of Fort Sumter this searchlight was transferred to a new emplacement to prevent reinforcement. As a matter of fact, the distance was about 1200 or 1400 yards but from the description the light was very satisfactory; so that the searchlight not only in its late development but in its very inception was an American invention.

MR. BASSETT: From the first searchlight that Dr. Bell has just told us about, up to the searchlight of 1915 or even 1916, we have the impressive list of uses of searchlights that was read in the first part of this paper; including all sorts of light barrages, searching for and watching enemy movements near and far, and general field uses of the searchlight. When the war started, the British, French and Germans were well equipped with field searchlights for these uses but during the first years of the war it was quickly discovered that all of these uses were obsolete in the new forms of warfare. By 1916 most of the searchlights had been withdrawn from the active zones and in France alone there were hundreds scrapped in what they called "the grave yard" just outside of Paris and for a time it looked as though the military searchlights were doomed as an asset to an army in the field. But with the death of the old field searchlight, there simultaneously sprang into being this new use of anti-aircraft defense which was the immediate answer to the new night bombing tactics. I think this new searchlight will play a more important role in modern warfare than the old searchlight ever played in its day. It is interesting to all of us to realize that this has meant a completely new development. The old searchlight which was used for field work did not lend itself readily to anti-aircraft work and during

the past three years it has been necessary to really revise the design of searchlights for this new use. The searchlight as it now stands, is hardly recognizable when compared with the pre-war searchlight and the tactics are completely different from the tactics that were used when the searchlight was hauled by mules up to within a few hundred yards of the enemy. I am sorry that pictures of the most recent developments have not been shown. The objects in view in developing the new light, were to have it as light as possible, to eleminate all automatic mechanism, to use the largest reflector possible without impairing the portability of the outfit. The British, French and Germans used lights with mirror diameters of 36 and 44 inches. This was about their limit since they could not lug anything larger around. The new design of American light, which is called the Open-Type light, and which was a result of Major Lewis's visit from the other side back to this country during the war, made it possible to put into the field a 60-inch searchlight, giving a beam which would run in the neighborhood of 800 to 900% greater than the French searchlights and which actually weighed not a bit more than the French lights. A great deal of credit is due to Major Lewis for personally returning to the United States and really showing the manufacturers and the army folk on this side, just what they were up against on the other side. As was the case with a great many things, the development on this side was quite out of phase with the need on the other side because the liason was very poor and we would learn of things six or eight months after the need had been felt on the other side.

Mr. Dickerson: I think there is one other item of special note that should be recorded at this time. A meeting with army officers was held in Schenectady on May 30 and in Lynn on May 31, at which time a rough sketch of a proposed open type searchlight was presented and approved with suggested changes. Ten days later this searchlight was completely built and operated. It was generally satisfactory and could have been put into field service. However, it was deemed advisable to perfect certain details so it was necessary to make another model. The present standard open type searchlight is similar in design to this original

model but possesses all the refinements of a finished piece of apparatus.

The following questions were asked:

1. Did these searchlight beams have to move very suddenly to follow the aeroplanes? Did the bombing aeroplanes do any fancy stunts in the air to avoid missiles?
2. How much area did the beam cover compared to the size of the plan?
3. Why are large parabolic reflectors more powerful than the smaller ones?
4. Do you mean that the large mirror takes in a larger proportion of the entire sphere of illumination than the smaller mirror?

LIEUT. BLAKESLEE:

1. The enemy bombing aeroplanes did attempt to manoeuvre and dodge the light but the movement of the light itself to enable it to follow the aeroplane was very small because a sudden movement would cause the beam to go at such a rate of speed that the eye could not discern it.
2. About two or three times the length of the aeroplane.
3. A parabolic mirror increases in focal length as it increases in diameter. A three-foot mirror has a focal length of 15 inches and a five-foot mirror has a focal length of 25 inches. The longer focus gives a smaller angle of spread to the beam and in this way it is possible to increase the intensity of the beam with a given source of light in proportion to the square of the focal length of the mirror. This gives a difference of beam intensity between the 36 and 60-inch mirrors of about three times. The remainder of the nine fold increase that I mentioned, is made up of an increase in the brightness of the source of light, in which we were also superior to the French.
4. A large mirror takes in the same solid angle of light but it throws it out within a smaller solid angle and therefore the amount of light in the beam is greater but the beam spread is smaller.

G. H. STICKNEY: Perhaps the relation between the focal length and the spread of beam will be clearer if we consider the light falling on a single point of the reflector. Since the carbon has appreciable dimensions, it is evident that one point on the reflector receives light rays in the form of a cone, of which the point on the reflector is the apex and the glowing tip of the carbon the base. Since the angle of reflection of a light ray must equal the angle of incidence, it is evident that the reflected light emanating from the point will be in the form of a cone of the same angular pitch. If we use a reflector of greater focal length we will increase the distance from the carbon tip to the point, and thereby reduce the angle of the cone. The result is that the reflected light will be in a narrower cone, from which it follows that the spread of the beam will be less.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

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THE ELECTRIC LIGHTING OF RAILROAD SIGNALS.*

L. C. PORTER AND F. S. STALLKNECHT.

Ever since the first steam locomotive was put into service, signals of some sort have been used for the night operation of trains. Originally bonfires were used for this purpose, but they were soon superseded by oil lanterns which were later improved by the application of lenses and the use of long-time burners. Such equipment to-day is the most generally used railroad signal equipment.

With the growing application of electricity, it was natural to apply it to railroad signal service. For several years, the moving semaphore blades of signals have been operated by electric motors utilizing primary battery current, which is also extensively used for energizing track circuits that form such an important part of present-day signal systems. In later years, electric lamps have been used in place of oil lanterns for signal work but only to a limited extent. Along some sections of the railroads, these electric lamps have been operated from local power circuits, and it is natural, that where roads have been electrified (which usually occurs only in the neighborhood of important terminal points), the same alternating current used for the propulsion of trains has been utilized for operating signal functions, including the lighting of signal lamps. In remote cases, gravity and storage batteries have been used as the source of energy for the lighting of signal lamps, but the battery which offers the greatest possibilities for this class of work, and the one which is rapidly coming into general use for the purpose, is the caustic soda primary cell.

Considering the obvious advantages of the electrically lighted

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signal lamp over the oil lamp, one marvels that it has taken railroads so long to make the change. Recently, one of Mr. Edison's engineers went to him with a problem in connection with the use of primary batteries for this service, but Mr. Edison was not especially interested, because, as he said, "You're working on something which *must* have been done years ago! Railroads are no longer using the oil lamp for lighting signals!" It took not a little argument to explain to Mr. Edison that notwithstanding the rapid progress which has been made in the application of electricity for other purposes, the railroads have clung steadfastly to the oil lamps in connection with signal lighting.

Before going into the mechanical and electrical details of the apparatus involved in the lighting of signals from primary batteries, it will be interesting to consider the reasons railroads, after all these years, are coming to the use of electric lighting. Probably the one factor which has done most to hurry the decision, is the steadily increasing cost of labor. Scarcely a month passes, but that the railroads of the country are confronted with some new labor problem which usually involves an increase in wages and a consequent increase in the cost of operation. Anything which in these days, makes better and more economical use of labor and decreases the cost of operation, is likely to get the interest of those who are vested with responsibility of railroad management.

Although the standard oil lamps are equipped with founts of generous size and long-time burners, they require frequent cleaning and their wicks must be as frequently trimmed. At the best, every oil lamp used in the operation of signal apparatus must be cleaned at least once a week. On some roads it is standard practice to attend to these details every three or four days. When it is realized that the care of these lamps is a responsibility of railroad maintainers whose sections range from five to forty miles in length, and when it is realized that these maintainers must carry oil in bulk from their headquarters to the most remote locations under their care, some idea will be had of the seriousness of the labor item involved. There is the further problem of bringing oil in bulk from the storehouse to the maintainer's shack, which adds another important item of labor.

The electrically-lighted signal lamp needs practically no attention. The statement has been made by Signal Engineers who have been conducting exhaustive tests on electrically lighted signals, over a long period, that with the exception of cleaning lenses some of their locations have not required attention once in two years! It is not uncommon in these tests for a lamp to run one year without attention, so it is conservative to say that the average electrically-lighted lamp will not need attention more often than twice a year, which, when compared with the semiweekly attention which oil lamps must have, gives a fair idea of the labor saving involved in the adoption of the new equipment.

Entirely apart from the labor saving which it produces, the electrically-lighted signal lamp is cheaper to maintain, and it is a far cleaner maintenance proposition. It eliminates the frequent failure of oil lamps to burn in high winds and under other unfavorable weather conditions. Those of us who travel extensively and like to protest when trains are late, little realize how seriously traveling at night is affected by the familiar "lights out." Some time ago, the "crack" train on one of the big roads of the country was delayed one hour and ten minutes traveling 284 miles during a high wind storm because of the failure of oil lamps to indicate the condition of signals. The electrically-lighted signal lamp practically never fails. This, we shall see, is due very largely to the development of a practical low voltage incandescent lamp having a filament designed to outlast the life of a primary cell.

It is no wonder that the railroads of the country are beginning to see the advantage of the reliable electrically-lighted lamp, with its constant and brilliant light, over the uncertain flicker of the antiquated oil lamp.

The initial cost of equipping one signal with an oil lamp and maintaining it for a year is in the neighborhood of $31.00. Where local power circuits supply the current, and where alternating current is utilized for the propulsion of trains, the cost of the initial installation of an electrically-lighted lamp and the maintaining of it for a year is in the neighborhood of $23.00. Storage battery installations and the maintaining of them for a year run pretty close to $80.00. The initial installation of an electrically-

lighted signal operated from *primary battery current,* and the maintaining of it for a year, is a little in excess of $50.00.

It is natural to ask, then, if the cost of an oil lamp for the first year is only $31.00, as against $50.00 for the electric lamp, utilizing primary battery energy, how can the claim be made that the latter is less costly? The answer is found in the fact that after the initial installation, the yearly maintenance cost of a lamp operated from primary batteries is approximately $4.25, as against approximately $24.50, for the cost of operating an oil lamp for the same period. Here again we have a striking example of the necessity of making an extra investment initially to produce a continuing future saving. (The cost figures given above are estimates based on present conditions.)

Now let us review some of the work which has been done in making practical the application of Mazda lamps for this class of service, bearing in mind that the original problem was to produce a filament which would outlast the life of the standard railroad primary battery, and, at the same time, consume a minimum amount of current and produce a light which would equal in brilliancy and spread the beam obtained from the broad flame of an oil lamp.

It perhaps will be worth while going farther, to review some of the fundamental principles of projection with respect to their application to the problem in hand.

If it is desired to collect the light emitted by a lamp and to project it in the form of a beam, there are two general methods of accomplishing this,—one, by the use of a lens, and the other by the use of a parabolic reflector (Fig. 1). In the former case, the light rays are refracted, or bent, as they pass through the glass; in the latter they are reflected from the surface of the mirror.

The question is frequently asked, "why not combine the two and thus utilize all of the light flux?" This is not practical because the points on the reflector become secondary light sources for the lens, which bends the rays therefrom, but in such a manner as to scatter, rather than concentrate them as is done with those coming directly from the primary source. This is illustrated by Fig. 2A. A reflector may, however, be combined with a lens provided the reflector is a spherical mirror. With the light source at the center of curvature of the mirror, an inverted

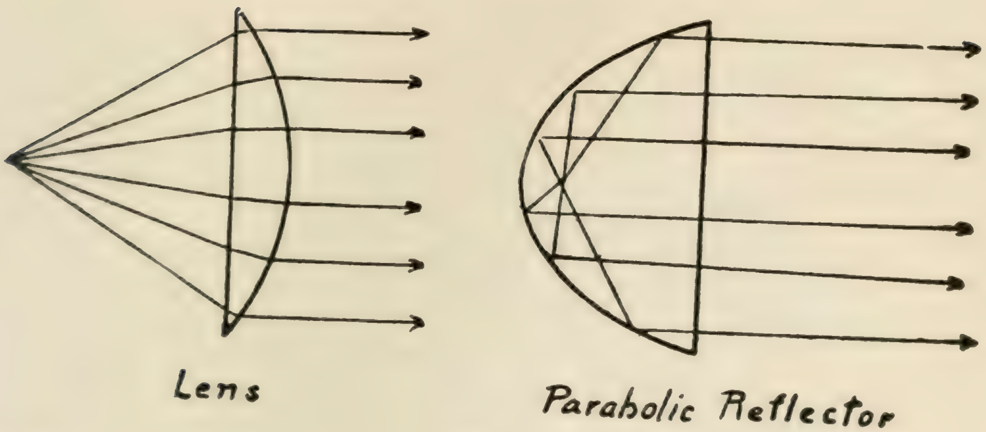


Fig. 1.

image of the source will be thrown back onto the source itself, thus materially increasing the light projected by the lens. (Fig. 2B.)

It is interesting to note the relative amount of the total light flux caught and projected by a lens and by a paraboloid. Of

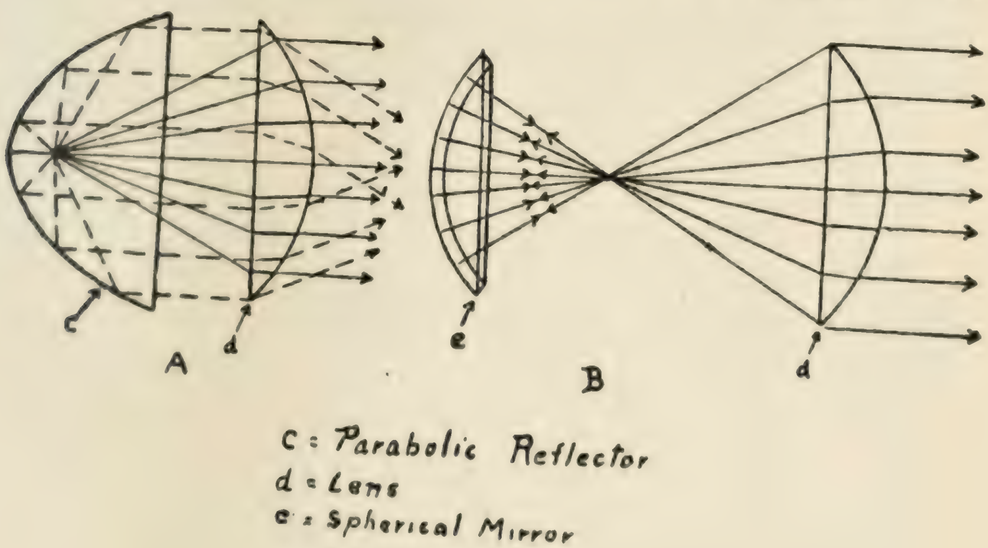


Fig. 2.

course, this depends somewhat upon the design of the two units in question but may, in a general way, be represented as in Fig. 3, the shaded portions of the circles representing the light flux utilized.

There are various factors which effect the spread and intensity of a beam projected either by a lens or a reflector—notably the

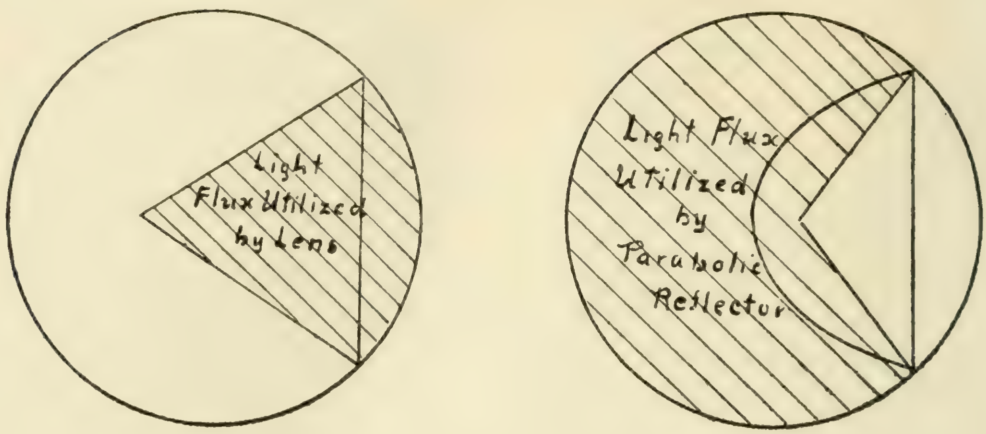


Fig. 3.

size of the light source. Fig. 4 shows clearly that the larger the source the greater will be the spread of the beam. The same amount of light flux spread out over a large area must necessarily illuminate that area to a lower brilliancy than if it were all put onto a small area.

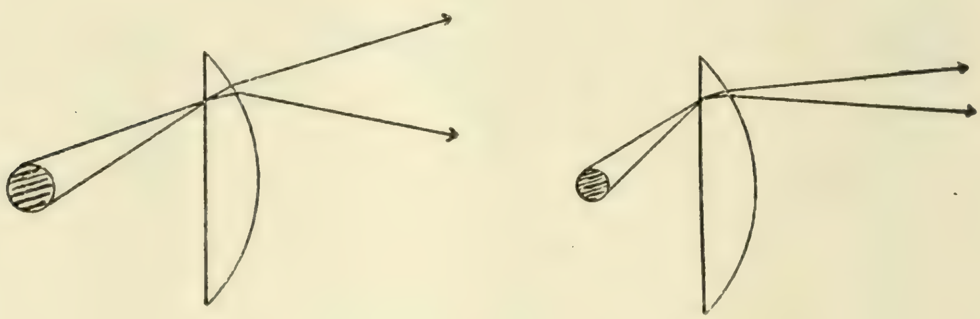


Fig. 4.

A very interesting test was made to illustrate the above. Using six lamps, of different filament concentrations, each was run at an efficiency which caused it to omit exactly 100 spherical candle-power so the total light flux from each lamp was equal. They were in turn focused in the same reflector and the beam candle-power measured. Fig. 5 shows the relative size of the lamp filaments and the enormous difference in the intensity of the projected beams caused by the size of light source.

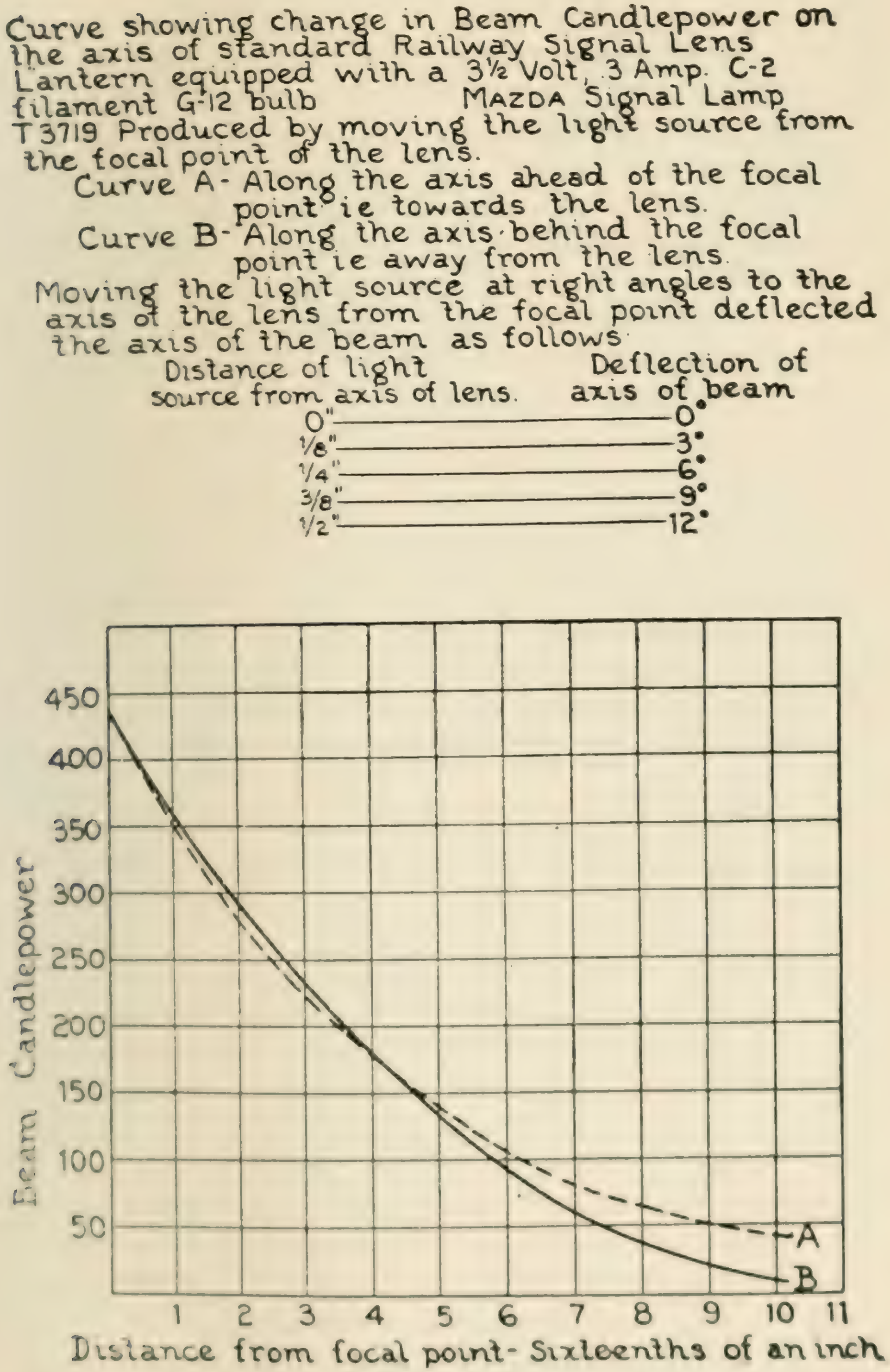


Fig. 6.

In addition to the size of the light source, its position with respect to the focal point of the lens or reflector with which it is

used materially effects the distribution of the light flux in the beam. Fig. 6 shows how rapidly the intensity of light in the beam from a semaphore lense falls as the light source is moved along the axis either ahead of or behind the focal point. This does not materially lessen the total amount of light projected forward but spreads it out over a greater area as illustrated by the photo of the beams from the standard lens with the light source at the focal point, ¼ in., and ½ in., away from it respectively. (Fig. 7.) If the light source is moved sideways instead of along the axis not only is the intensity of the beam lowered but its direction is changed. Moving the source to the right throws the beams to the left, moving it upward throws the beam down, etc.

It is exceedingly important, therefore, when dealing with any form of projection apparatus such as signal lenses or reflectors, search lights, auto and locomotive headlights, stereopticon lanterns, etc., etc., to see that the light is correctly focused. Due to necessary variations in manufacture most projection equipment is provided with means for adjusting the relative position of light source and reflector or lens for focusing purposes. When a renewal lamp is inserted it should be refocused as the filament may not come in exactly the same position as that of the previous lamp.

There were two very difficult factors to overcome in replacing the broad uniformally luminous oil flame as a light source, with the filament of a Mazda lamp. Commercial reasons made it advisable to retain the lantern and lens already in use with oil lamps. The wide flame of the oil lamp itself easily "filled" the lens so that its entire surface appeared luminous viewed from almost any angle. The spread of the beam was about 3°, having a fairly uniform intensity of about 24 beam candle-power throughout. It was necessary to reproduce or better these conditions with filament occupying but a very small percentage of the area occupied by the oil flame and operating at a brilliancy of about 426,000 millilamberts or 875 candle-power per square inch instead of 1460 millilamberts or 3 candle-power per square inch. Greater area of light source could be obtained by increasing the length of filament in the lamp, but this would increase the wattage consumption and therefore run down the batteries too rapidly. Taking these factors into consideration a lamp was developed having a 3½ volt

230

Fig. 5.

[illegible] Candle-power (Spherical) Mazda Lamps having Filaments of Different Size for Testing Purposes

Light Source Dimensions MM		Beam Candle-power	Lamp Used	
Diameter	Length			
2.8	6.5	462,000	6 volt 108 watt G-30 bulb Mazda C headlight lamp –	A
6.0	5.0	221,000	32 volt 100 watt G-30 bulb Mazda C headlight lamp –	B
6.5	6.5	142,000	110 volt 100 watt G-25 bulb Mazda C stereopticon lamp –	C
8.0	8.0	37,000	110 volt 100 watt G-30 bulb Mazda B stereopticon lamp –	D
25.0	5	12,700	110 volt 100 watt PS-25 bulb regular Mazda C lamp –	E
30.0	68.0	3,800	110 volt 100 watt G-35 bulb regular Mazda B lamp –	F

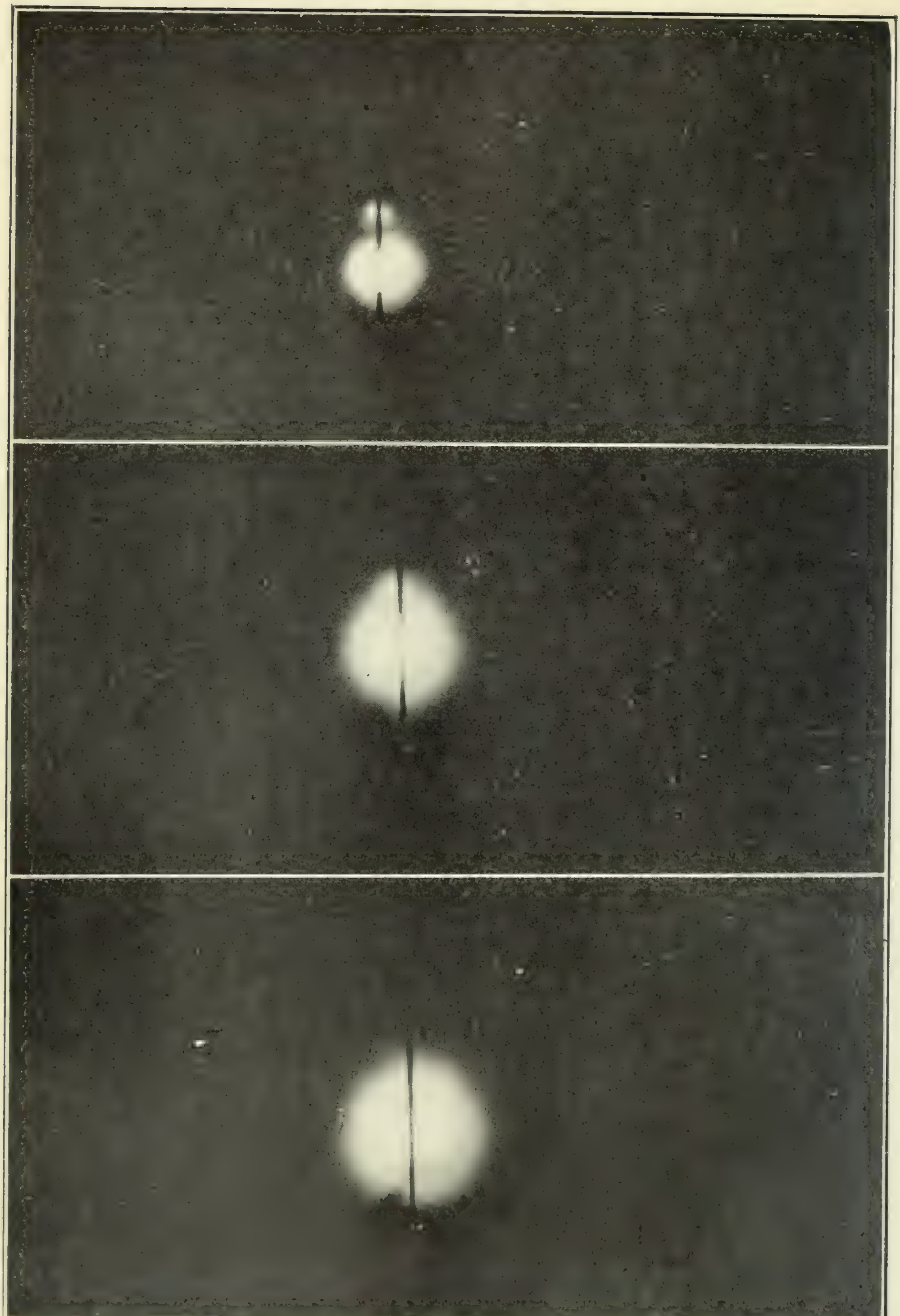


Fig. 7.

Top—Lamp at focus. Center—Lamp ¼″ from focus. Bottom—Lamp ½″ from focus.

3½ VOLT RAILWAY SIGNAL LAMP

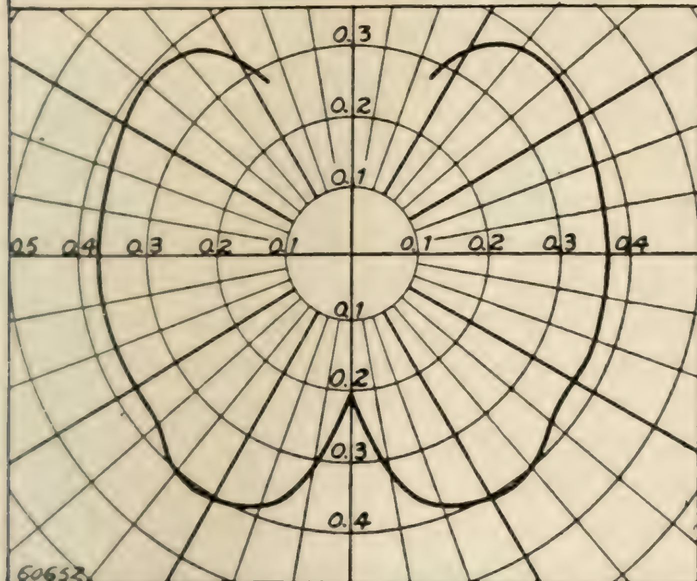
C-2 FILAMENT G-12 BULB CLEAR T-3719

LAMP ______________________________ CLEAR

VOLTS 3.5 ______________________________ Amps .30

PHOTOMETRIC TEST

INITIAL DISTRIBUTION OF CANDLE-POWER IN A VERTICAL-PLANE

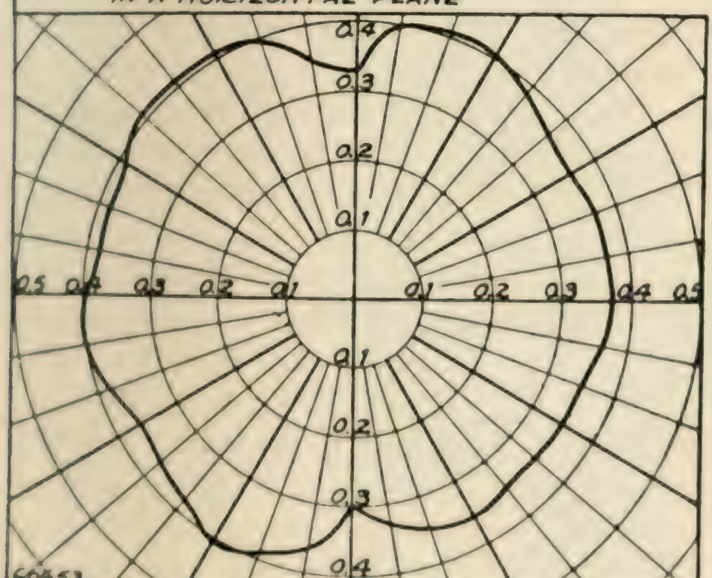


ZONE 0 TO	LUMENS LOWER HEM.	90° TO 180°	UPPER HEM.
10	0.025	100	0.410
20	0.129	110	0.805
30	0.315	120	1.185
40	0.668	130	1.539
50	0.973	140	1.843
60	1.308	150	2.070
70	1.680	160	2.210
80	2.070	170	
90	2.470	180	
S.F.D.			

READINGS TAKEN AT ONE FT. RADIUS
CLEAR LAMP OPERATED AT 3.5 VOLTS
AVERAGE OF TESTS IN 3 PLANES 120° APART

PHOTOMETRIC TEST

INITIAL DISTRIBUTION OF CANDLE-POWER IN A HORIZONTAL PLANE



READINGS TAKEN AT ONE FT. RADIUS
CLEAR LAMP OPERATED AT 3.5 VOLTS
EQUIPMENT

AVERAGE HORIZONTAL C.P. = 0.37

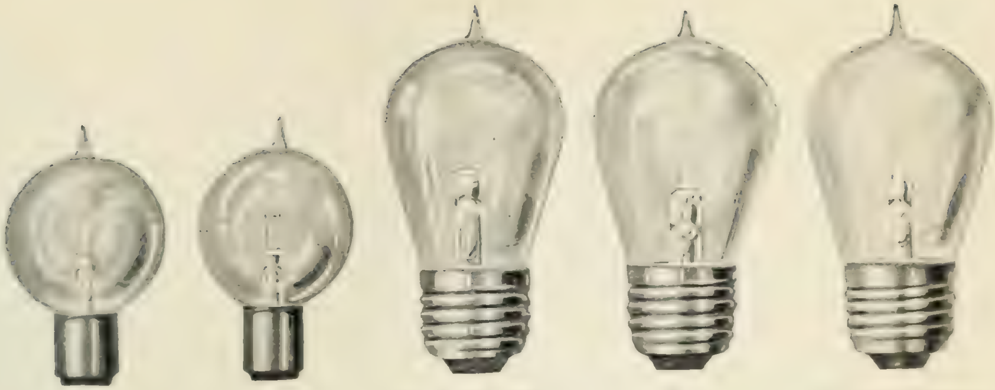
Fig. 8a

filament operating at 0.3 of an ampere. Numerous filament shapes were made and tested in the oil signal lanterns to determine which would give the most satisfactory light distribution. Fig. 8 shows some of the different filament shapes that were tried.

The very highly concentrated filament C-6 was found not only to give too narrow a beam but also to be too small for practical focusing under service conditions. The single loop filament S-2 did not give sufficient intensity of light on the axis and the distribution of the light was not uniform. In studying the effects of these various shaped filaments not only were photometric distribution curves made of the lamp itself as well as the combined lamp and lens, and photographs taken of the spot of light projected, but lamps were installed in actual signals in service and the comments of locomotive engineers, as well as railroad men obtained. The filament finally decided upon was the C-2 form, giving a light distribution shown in Fig. 8 A. This type of filament not only gives a high beam candle-power along the axis but also good spread and at the same time completeley "fills" the lens and is fairly easy to locate at the focal point. It is equally effective when used in the present oil signal lantern or in the parabolic reflector lantern (Fig. 9 A and B). Distribution curves from these two units and also from the oil lantern are shown in Fig. 10. Curves were also made from the same lamp used back of a spreadlite lens (Fig. 11). The effect of having the light source in or out of focus with this lens is shown by the photos of the beam (Fig. 12). Having determined the best shape of filament and the approximate voltage and ampereage, the next step was to fix the efficiency and, what is inseparably tied up with it, the life of the lamp. To do this involved a study of the discharge characteristics of the batteries used as a source of power. The voltage of any battery is not constant but begins to drop the instant current is taken from the battery. If the load is constant the average voltage throughout the life of the battery will be materially lower than its initial voltage. If the load is intermittent this will still be the case, but the average will not be so low as with constant load, due to the fact that the battery recuperates somewhat during the rest periods.

These factors must be taken into consideration in the design of an incandescent lamp for use with a battery. Fig. 13 shows

232a



C 4 C 6 S 3 Anchored S 2 S3 Unanchored

Fig. 8.

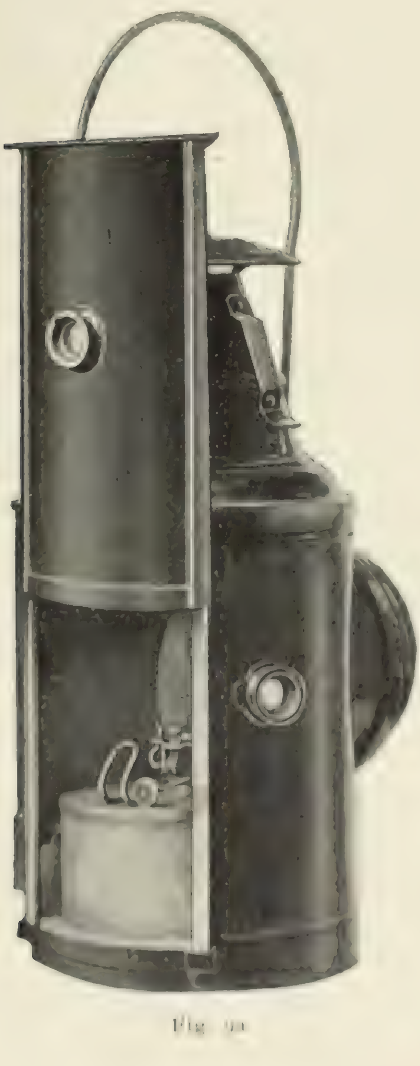


Fig. [illegible]

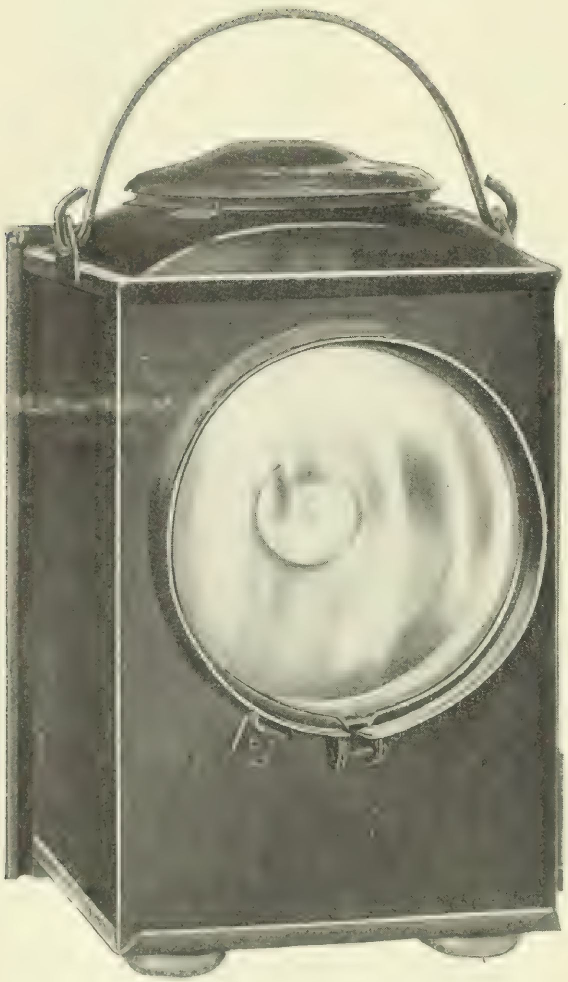


Fig. 9b

typical discharge curves of different types of batteries. It is obvious that a lamp designed to give good service on the dry battery discharge curve would give a very short life if operated on a storage battery, even though each might have the same

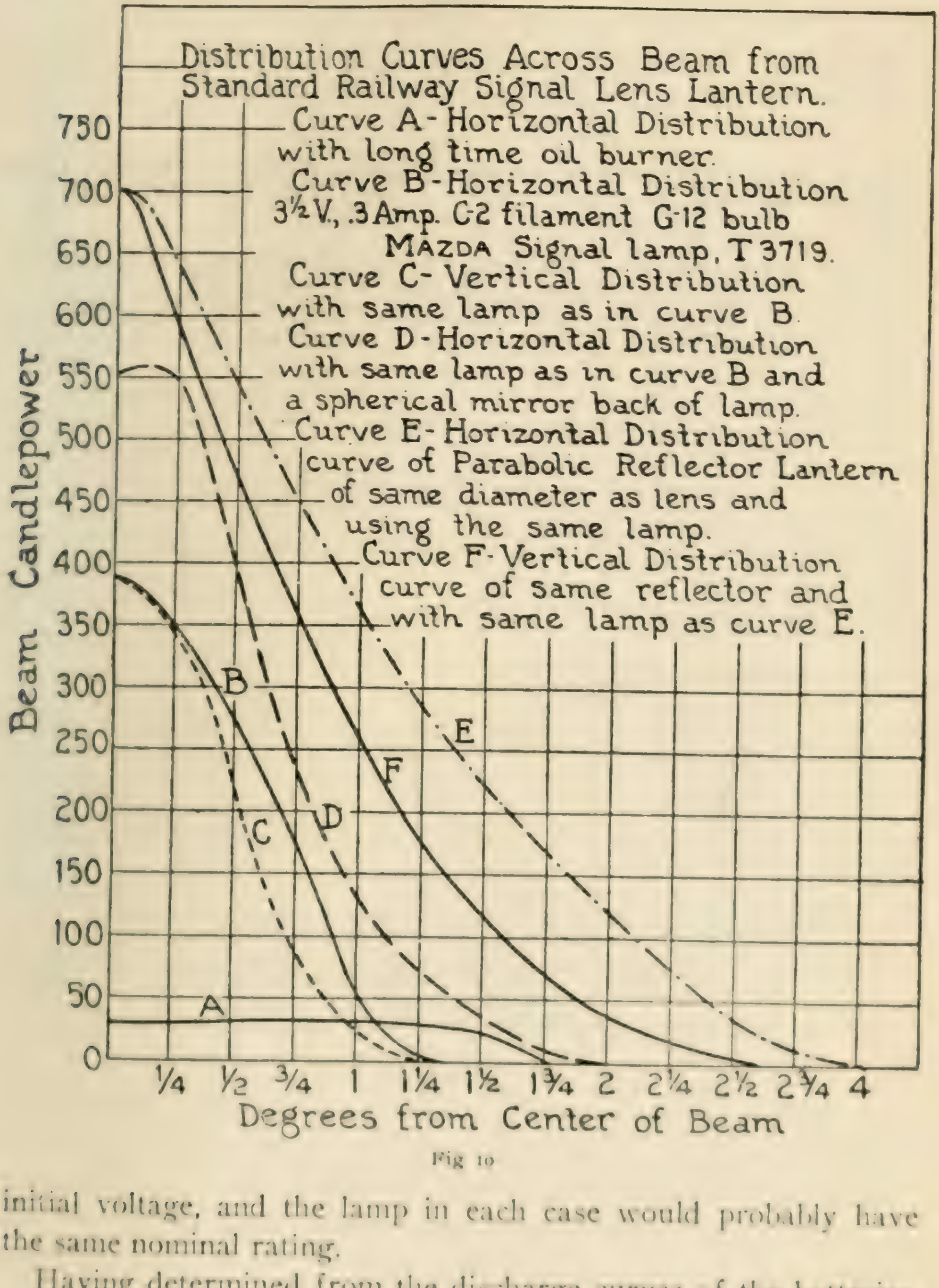


Fig 10

initial voltage, and the lamp in each case would probably have the same nominal rating.

Having determined from the discharge curves of the batteries, (taken under operating conditions with an actual lamp load), the

correct voltage for the lamp, the efficiency was fixed at such a value that the lamps would outlast the life of the battery with a factor of safety. For this reason the lamps should be renewed every time the battery is renewed, thus preventing interruption to service through lamp failures. As the majority of signals for this system burn two lamps in multiple and are arranged by means of relays so that the lamps light only on the approach of a train and

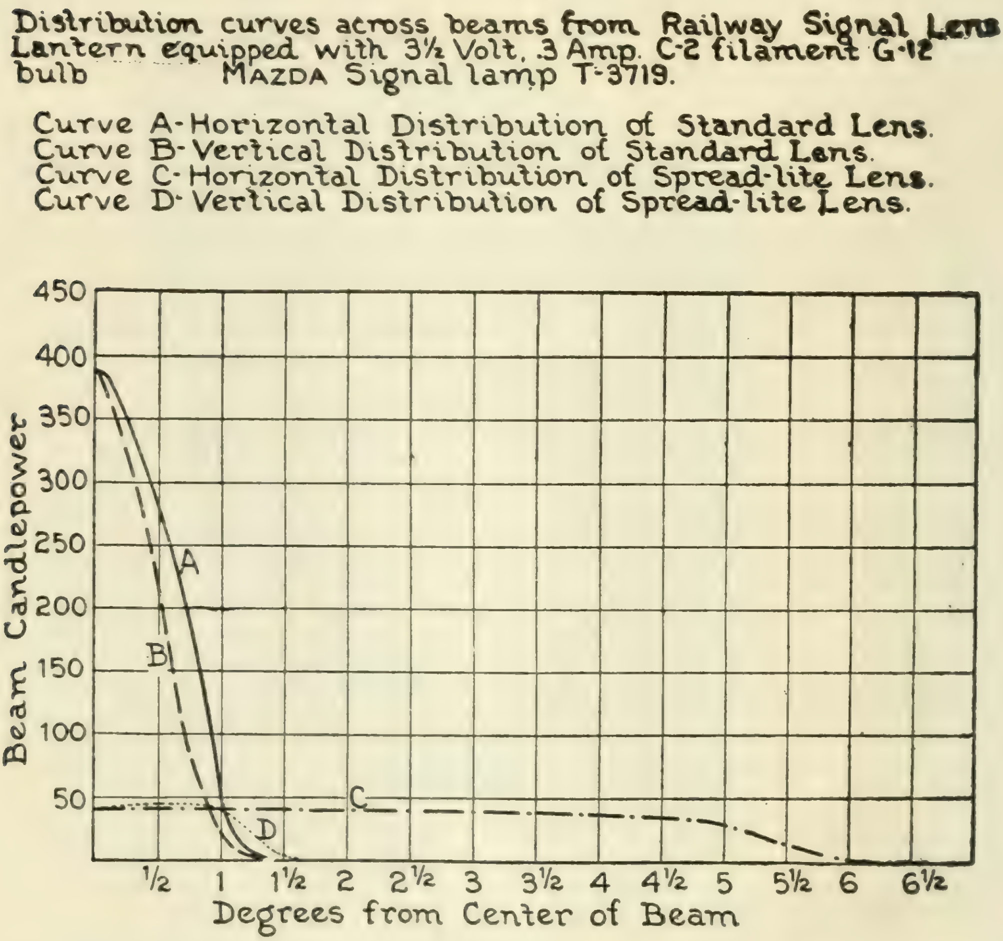


Fig. 11.

are extinguished as it passes into the next block, it is estimated that the batteries and lamps will need attention under average railroad service not more frequently than twice a year. The four cells of Nickle Alkaline Storage Battery standardized for signal work have a capacity of 500 amperes hours. Two lamps in multiple would draw 0.6 amperes hence the lamps and batteries will have at least 800 actual burning hours. As a matter of fact, due to the

decreasing voltage throughout discharge, the average current consumption will be somewhat less than 0.6 amperes with a resultant increase in life. To eliminate as far as practical the possibility of lamp failures, the efficiency of these lamps has been set to give a life of about 1200 hours.

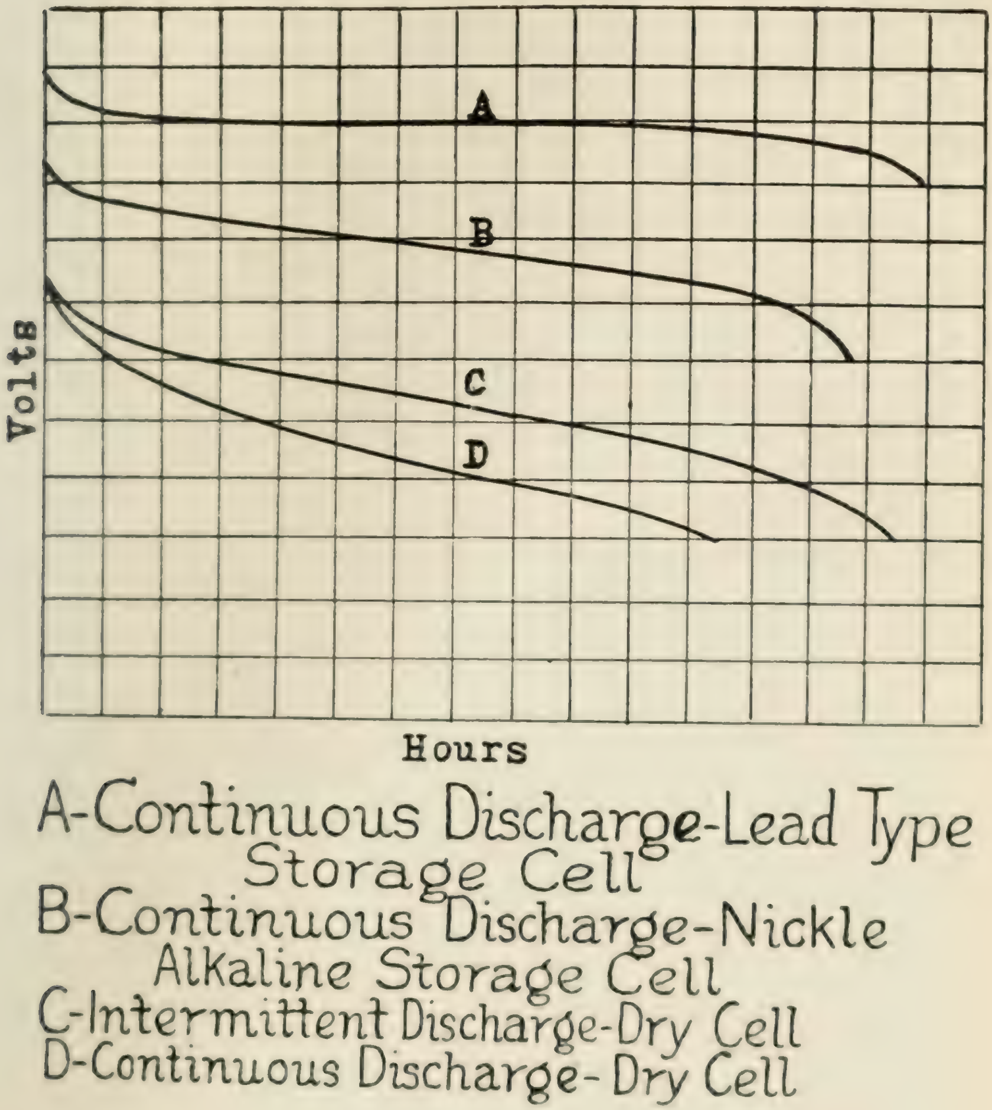


Fig. 13

Having fixed the electrical characteristics of the lamp, about all that remained was the determination of the bulb size and base. As it seemed probable that while the majority of the lamps would at first go into the present oil lanterns, eventually new and more efficient lanterns using parabolic reflectors would come into gen-

eral use. In order, therefore, to have only one type of bulb which might be used interchangeably in either lantern, it was determined to use a G-12 bulb, double contact bayonet base with a 1¼ in. light center length. This may be superseded by an S-11 bulb of the same light center length, because it is a stronger bulb and one in which the filament can be more accurately located than in the G-12.

Now let us look briefly to the signal lanterns themselves. At first it seems that the problem of converting the common oil lamp of to-day to accommodate the incandescent lamp would be a very simple one. Probably the first oil lamps to be converted were those in the vicinity of railroad stations where A. C. power was available. This power was brought to the signals and ordinary house lighting lamps were suspended through the chimneys of the oil lamp housings. Usually these lights were controlled by the station agent and burned only at night. Later it was decided that the lamps used in this manner were of unnecessarily high candle-power and that a saving could be effected by using lamps having semi-concentrated filaments taking from two to three watts. These lamps gave such good service and showed so many advantages over the oil lamps, that the question naturally arose as to how lamps in outlying districts could be electrically lighted.

Various Signal Engineers in different parts of the country began tests using ordinary 6 volt automobile lamps in their lamp housings. In such cases primary or storage batteries were used as the source of current, but the discovery was made that although better light was obtained the current consumed made the experiment far from economical.

The development of the low voltage Mazda signal lamp, followed these experiments, and since this lamp is of the highly concentrated filament type it became necessary to provide an easy and efficient means of locating the light source at the focal point of the commonly-used optical lens.

Various adapter blocks were put on the market at this time. They usually consisted of a wooden block on which was mounted an ordinary lamp socket, with some more or less unsatisfactory means of adjusting the lamp up and down, and forward and back, so that the filament could be located at the theoretical focal point of the lantern lens.

236 ½

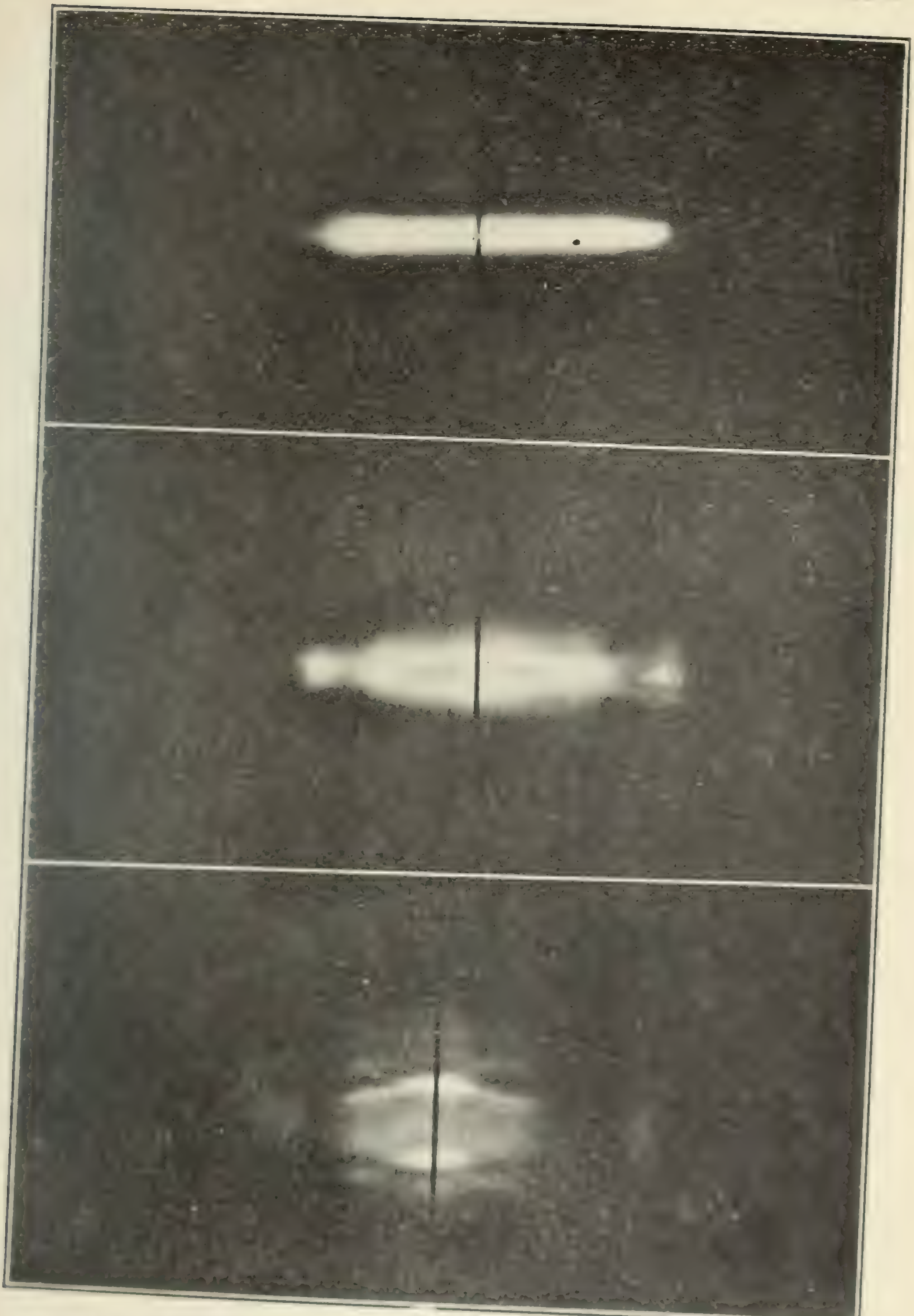


Fig. 12

Top—Lamp at focus. Center—Lamp [illegible]" from focus. Bottom—Lamp [illegible]" from focus.

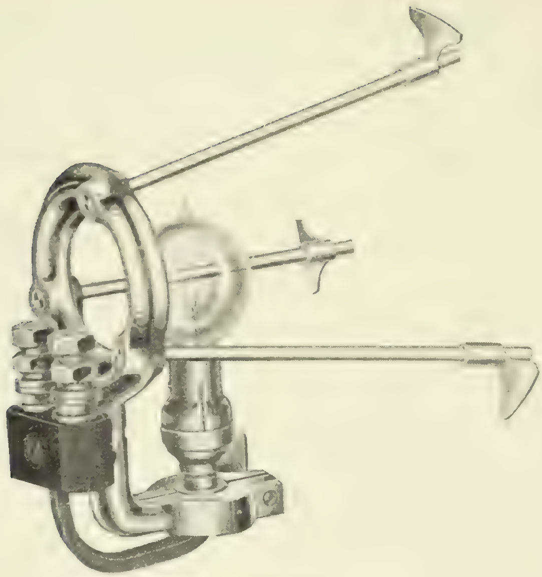


Fig. 14.

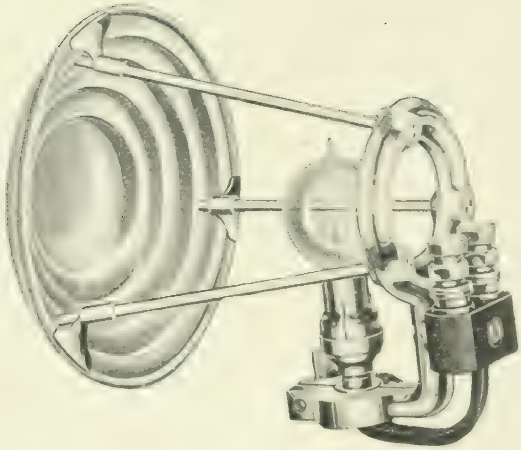


Fig. 15.

These adapters proved far more satisfactory than the earlier non-adjustable type, but their use involved so much trouble and so much uncertainty, that the railroad officials did not take to them with any special enthusiasm. In order properly to focus the filament with respect to the lens, when these adapters were used, it was necessary either to focus the lamps in place on the signal pole at night or remove the oil lamp housing to a dark room. Here a fixture similar to the bracket on a semaphore signal was provided to hold the lamp in an upright position while the light source was adjusted so as to throw the beam of light onto a mark on the wall indicating that the lamp was in focus. In the former case two men were needed for the job—one at the signal lamp, and the other, the observer as he was called, down the track, usually at the point where the engineer of an oncoming train would pick up his light indication. This work had to be done in the dark, by means of an exchange of signals with flashlights or lanterns, until the man on the top of the pole finally adjusted the lamp to suit the observer.

Needless to say, this method called for a great deal of care on the part of both men, and it was not particularly pleasant to be focusing a lamp out in the country on a bad night. This had a decided advantage over the dark room method because it automatically took care of variations in the position of the particular bracket to which the lamp was to be attached. Obviously the standard bracket used in the dark room work could scarcely be expected to take care of all the variations in adjustment of the lamp brackets found on the road.

It was but natural that those who had spent many nights out in the road in all kinds of weather, trying patience in the adjustment of lamps, should think out how electric lamps might be focused more effectively, with less labor and less wear and tear on the nerves, and this work be accomplished in the day time.

All the so-called adapters had been made, evidently, with the idea that they had to fit into the space at the bottom of the lamps formerly occupied by the oil founts. At least it is evident that this seemed to be the easiest way of converting oil lamps, but, as it developed, there were found to be lanterns in service having deep oil founts and others with shallow ones. This made it impractical to provide one wooden block adapter, taking its position

from the bottom of the fount, which would in all cases bring the lamp filament at the focal point of the lens.

It occurred first to the designing engineers that the difficulty of producing an adapter which would accommodate itself to variations in the construction of the lamp housing, could be met by locating the adapter from the one part of the complete lantern with which the light source must bear a fixed relation, *i. e.*,—the lens. The idea is so obvious that one wonders why nobody thought of it before, for it is far easier to adjust the filament of the lamp at the focal point of the lens by working directly from the lens itself, than to work from the bottom of the lantern with all its variations. The result of this reasoning is the adapter illustrated in Fig. 14.

The adapter consists of a simple casting equipped with a split ball-and-socket joint (in which is located the post and socket carrying the incandescent lamp), and three legs (each equipped with a lug of spring steel), which provide the means of attaching and positioning the adapter with respect to the lens (Fig. 15). The three legs ,which can be sprung inwardly and outwardly, slip into place against the corner of the first riser on the inside of the lens. This automatically locates the lugs between the lens and the lens housing, and when the lens ring is tightened down it presses against the lens which in turn presses against the lugs of spring steel, clamping them securely into place. Through the lugs, spring contact is maintained at all times between the adapter rods and the lens thus eliminating any danger of vibration which might produce breakage of lenses.

The ball-and-socket joint in the casting is controlled by a single wing screw. Loosening this screw permits the convenient moving of the lamp and socket, in any direction. Fig. 16 shows an adapter of different design particularly suited to switch lamps, which invariably have four lenses. With this adapter it is possible to use the one light source to fill all four lenses (Fig. 17). The same focusing device is used with this adapter as with the semaphore adapter.

The development of these adapters proved to be the solution of the problem of providing a satisfactory device for converting oil lanterns to accommodate incandescent lamps, but it did not of itself, take care of accurate focusing in the day time. If the

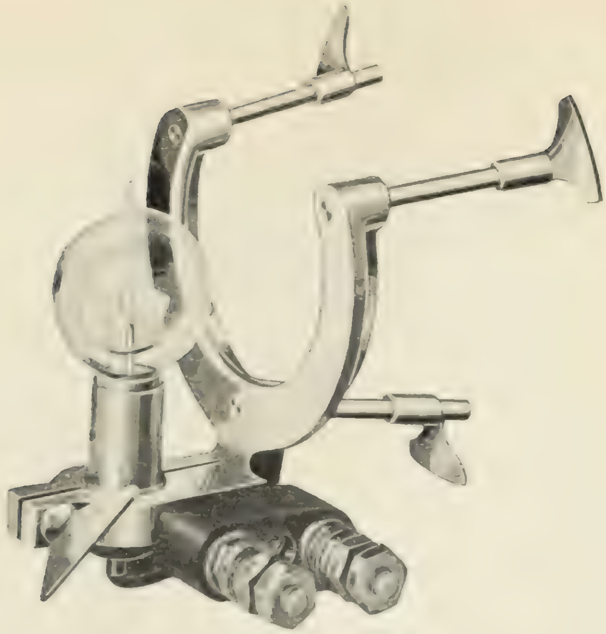


Fig. 16.

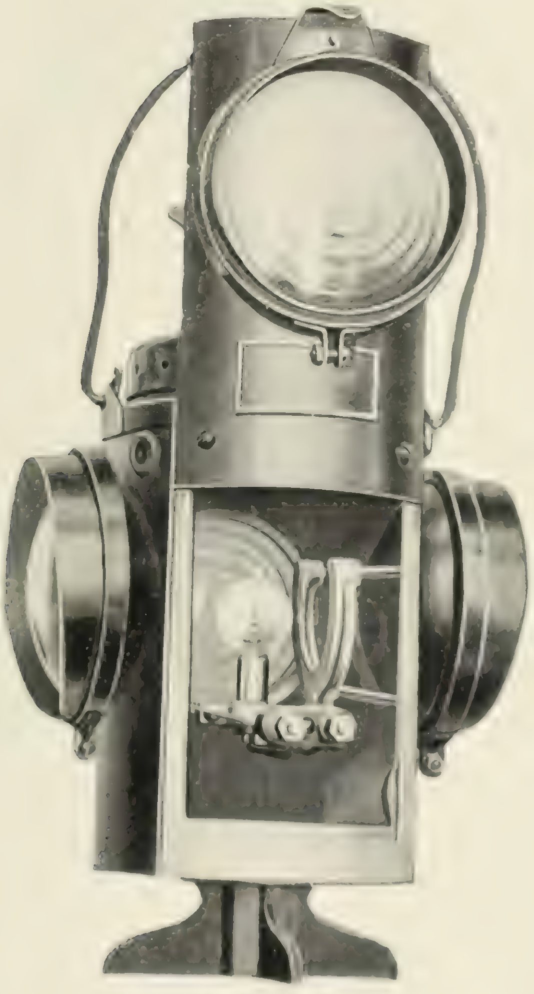


Fig. 17

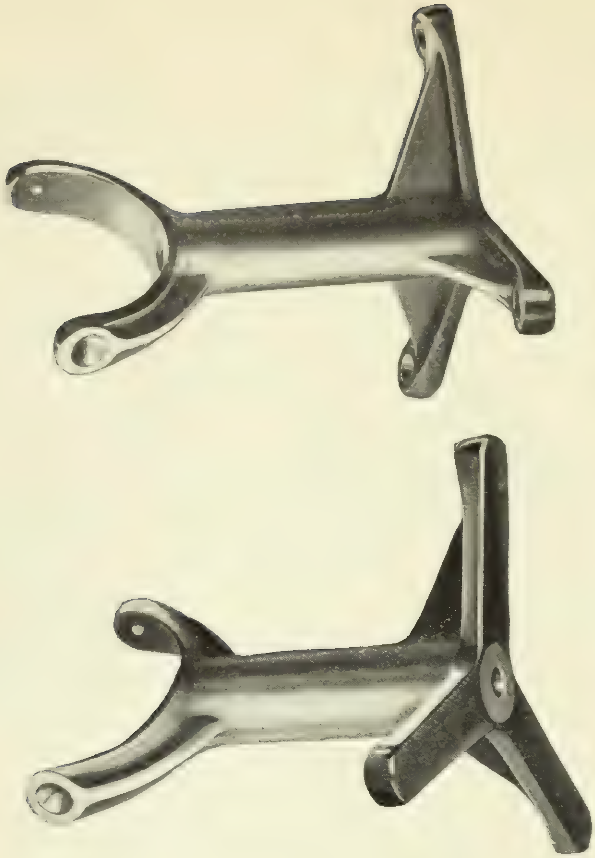


Fig. 18.

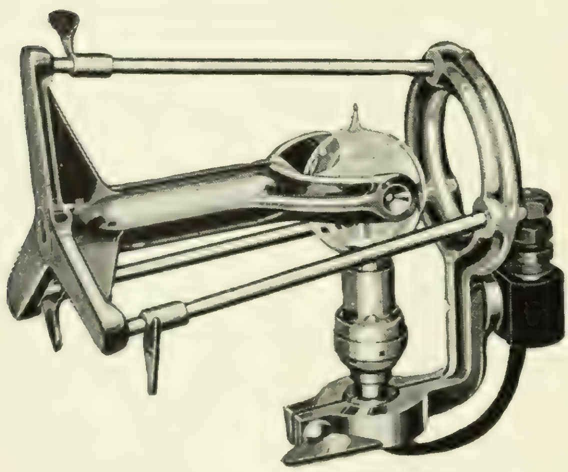


Fig. 19.

engineers had stopped when the adapter itself was developed, railroads would still have been confronted with the same old problem of the night focusing of lamps, or the alternative of unsatisfactory shop focusing.

This situation led to the development of one of the most interesting devices in the railroad appliance field—the focusing device illustrated in Fig. 18. This device unquestionably solves the problem of placing the concentrated filament of the electric lamp at the exact focal point of the lens at any time desired.

The lamp is focused in the adapter before the latter is inserted in the lantern. Holes are carefully drilled in the three feet at the bottom of the focusing device, into which the lugs of the adapter are fitted. The focusing device thus assumes the same relative position toward the adapter as the lens in the lantern, Fig. 19. Through the center of the device a hole is drilled, and holes also are drilled through the upper end of the two arms at the top of the device.

The intersection of the imaginary lines produced by sighting first through one set of holes and then through the other, is the theoretical focal point of the lens (Fig. 20). If it is desired to focus a lamp at night, it is a very simple matter to connect the lamp to a battery so that the filament will glow, and by sighting through the two sets of peep-holes, at the same time operating the set screw which controls the ball-and-socket joint, to bring the filament at the exact desired intersection. If focusing the lamp in the daytime the filament can readily be seen without lighting it. The adjustment is so easy and at the same time so accurate that it is a simple matter to go so far as to bring the wide part of the filament exactly parallel to the lens. When the adjustment is secured, the set screw is tightly clamped down and the focusing device is removed. The adapter is then ready to be attached, as already described, to any standard lens, in any standard oil lamp, with the certainty that the light will be absolutely in focus with that lens (Fig. 21).

It is not difficult to see the value of the adapter and the focusing device. They solve difficulties which for years have been thought sufficient to hold back the entire idea of lighting signal

lamps electrically. They utilize the maximum efficiency of the low voltage incandescent lamp, and place the focusing of lamps on a basis which is so certain that it is almost mechanical.

When the incandescent lamp is accurately focused with respect to the lens of the lantern just one more thing is necessary—the locating of the lantern itself on the lantern bracket of the signal in such a way that the maximum efficiency of the focused lamp is utilized in giving the engineer of an oncoming train his light indication at the proper point on the track. In other words training the axis of the beam at that point.

Here again the designing engineers have contributed a simple supplementary focusing device shown in Fig. 22. When this device is placed over the lamp bracket a sight is taken through the telescopic tube marked A. At the outer end of the tube are two intersecting lines. The lamp bracket is adjusted until the intersection of these two lines strikes the point down the track at which the engineer is to get his indication, and the lamp bracket is then tightly clamped in that position. Fig. 23 illustrates this device in service.

When the lamp is slipped over the lamp bracket it assumes the same position as the focusing device and the light is seen to best advantage at the point formerly indicated by the intersection of the lines at the outer end of the tube, which are mechanically constructed to indicate the focal axis of the lens.

Signal Engineers to whom these devices have been shown and explained, give it as their opinion that they provide the means of insuring the success of the entire electric lighting system. The devices are subject to all manner of further development, work in connection with which is now going on. The adapter, for example, is being made to carry a spherical mirror which catches and redirects the backward rays of light, thus increasing the over-all efficiency of the device. By throwing an inverted image of the filament back on to the filament itself, not only is the area of the light source larger but the volume of light projected by the lens is materially increased as shown by Fig. 10. Even at that it is far below what is possible by the use of a parabolic reflector. Not only will the latter device produce a higher average beam candle-power, but it may be sealed up moisture and dust proof. Fig. 10 shows the distribution curves from a converted

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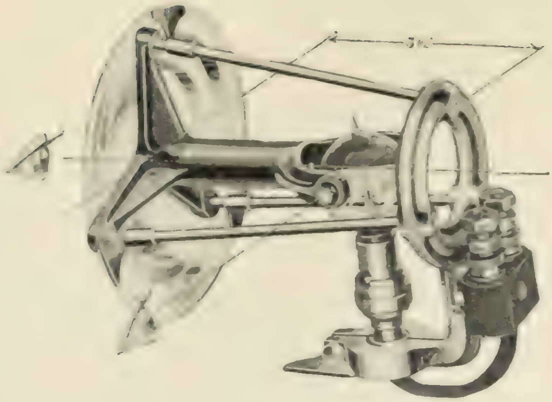

Fig. 20.

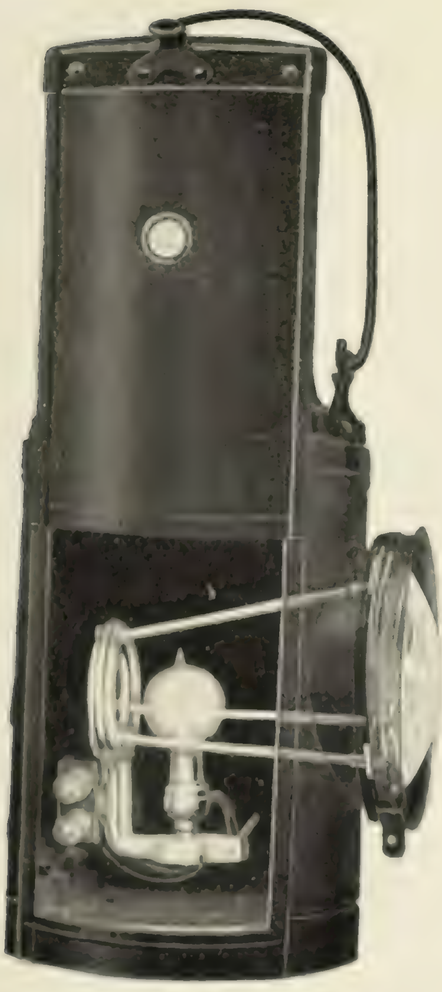

Fig. 21

Fig. 23.

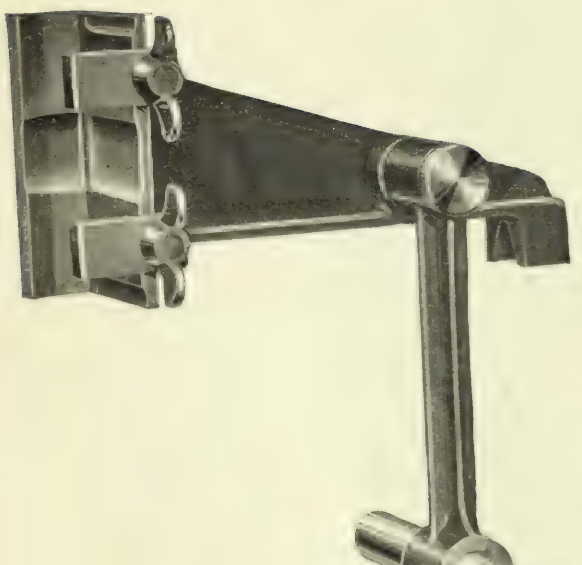

Fig. 22.

oil lantern and a parabolic reflector lantern of the same diameter using the same lamp as a light source.

In studying these curves it is interesting to note that on account of the greater percentage of light flux utilized by the parabolic reflector the intensity of the beam is higher throughout its entire spread; and slightly off from the axis it is materially higher. Fig. 24 illustrates this more fully. The angles of light flux utilized by the two forms of projectors, lens and reflector, are not

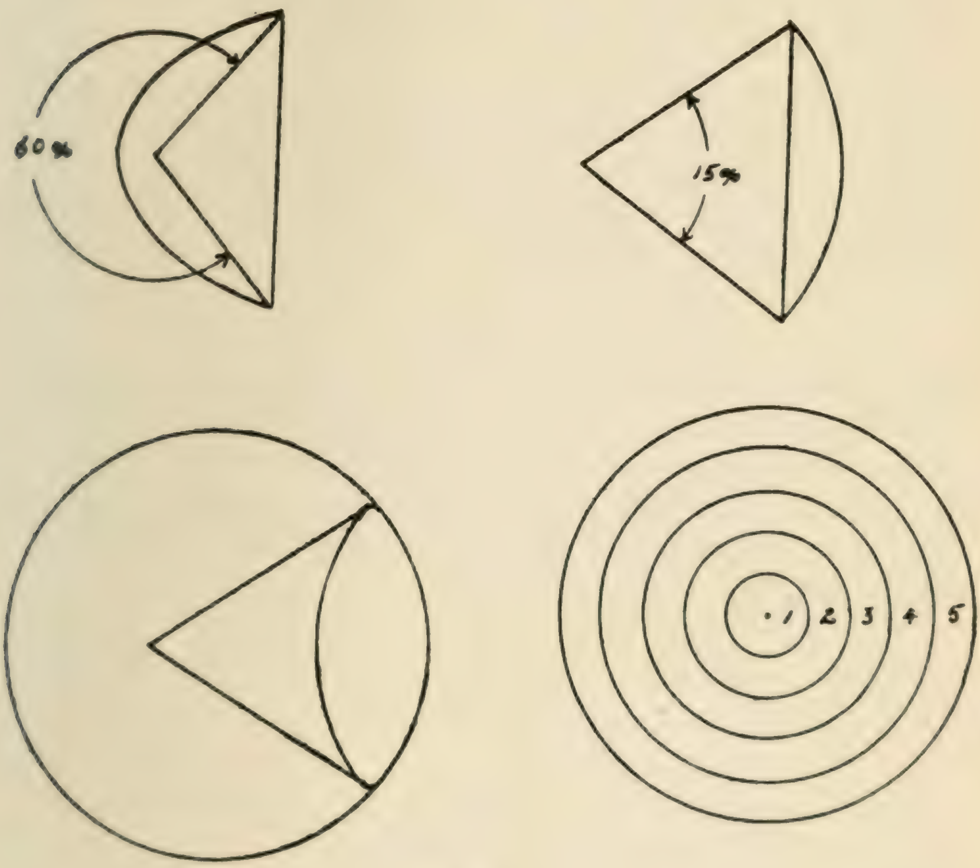

Fig. 24.

plane angles but solid angles cutting out portions of a sphere, hence the relative percentages of light flux utilized are greater than the plane angles intercepted between the ends of the diameter of the lens or reflector and the light source. In the particular case in question the relative useful light fluxes are about 15 per cent. and 60 per cent. of the total emitted by the lamp for lens and reflector respectively.

Referring again to the distribution curves (Fig. 10) the high intensity of light on the axis may not represent as large a volume or flux of light (as many lumens) as the intensity at say 3° from the axis. While this is much lower it is spread over a larger area as represented by section No. 3 in the lower right hand corner of Fig. 24. Total light flux measured in lumens being the product of the area and the average intensity on that area.

It is anticipated that the majority of initial installations will be converted oil lanterns due to lower cost, but as these lanterns wear and have to be replaced it would be good practice to install the reflector type of lantern.

In conclusion the authors wish to extend their thanks to Mr. H. F. Barnes in the Illuminating Engineering Department of the Edison Lamp Works and to the various men in the Edison Primary Battery Division for the assistance they rendered in obtaining the data given in this paper.

DISCUSSION.

MR. HAMMER: In the Patent Office Museum in Washington, one will find there that the first patent which was issued in which an incandescent lamp was employed, was for a signaling device on railroads. The lamp filed as a model is a platinum wire lamp which may be seen in one of the cases in the museum at the present day.

WHAT THE ILLUMINATING ENGINEER CAN DO FOR THE FIXTURE MANUFACTURER.*

BY W. R. MCCOY.

Gentlemen, I presume you are accustomed to listening to papers treating their subjects purely from a scientific viewpoint. May I ask you to forget the language of science a few moments and step out in the broad world of business where your abstract reasonings are made to take concrete form and where your ideas are made into lighting devices.

First of all, Gentlement of the Illuminating Engineering Society, we desire to pay you the homage that is due you. You have been and are invaluable to the fixture industry. While we are proud of the results of our efforts having developed the fixture from a thing to carry something that would give light, to an artistic decoration of the home as well as a lighting device, we do not forget that without your careful and painstaking researches we would not have had the material for our development. Your work is only begun and we wish you every success, for as you discover so shall we produce.

Your committee, when inviting us to join with you in this meeting suggested that we tell you what you could do for us. It was a happy thought and if we can hasten the day when all sham will be cast aside and we can work together with a clear understanding of each other's limitations, these limitations will grow less and less and things will be accomplished that we do not now even dream of.

The farmer must first know his soil or his prize seed may be wasted. So many of your ideas may not bring the result you hope for unless you know all about the ultimate producer, the fixture manufacturer.

Therefore, Gentlemen, I am going to answer your question, "What can the Illuminating Engineer do for the Fixture Manufacturer," in two words: "Know us." We want you to understand us. Know our problems. Realize that while it may be difficult for you to create, it may be much more difficult for us to

* Prepared for the meeting of the New York Section of Illuminating Engineering Society, January 8, 1920.

fabricate. Remember you are engineers, we are artists. Your first thought is the efficiency of light; ours, its appeal to the aesthetic sense. Remember the most efficient is never the most beautiful.

To illustrate this fundamental difference between us, let you and I wander into a room which instead of being illuminated with electricity is lighted by fragrant bayberry candles. I immediately catch the pleasing odor of bayberry and note the softness of the light, the flickering shadows, the delicate chasing and perfect proportion of the Sheffield candlesticks. To me it is beautiful and efficient for its purpose. I never give a thought to the fact that it may increase my oculist bill. You see and feel the same things as I do, but your training subconsciously calls attention to the poor illumination. You want to eliminate the shadows, make the light steady, conceal its sources and put the optician out of business. You would like to do all these things and retain all the better things that we have both found. Gentlemen, it can't be done.

Turn to fundamentals for a moment. The candle is your yardstick; you compare your greatest light-giving invention to its feeble flame. To you it belongs solely to science. It is of no less importance to us. It is the model that every manufacturer is using for home lighting. A large percentage of all fixtures for domestic purposes are of the candle type. The influence of the candle is seen in the slender arms of graceful sweep on the bracket or chandelier. It has been the cause of the greatest refinement of line and detail. To us it belongs to art. While we readily recognize its great importance to our respective endeavors, some of us have probably missed a mission it is trying to perform.

Let us realize that the modest little candle with its uncertain light of yellow is trying to bring us together and teach us that there is more to the word "efficiency" in those things that appeal to the eye and sense of refinement than the efficiency engineers would have us believe. It is trying to prove to us that home lighting is more than light. It is light so used that it appeals to every sense, practical and aesthetic, but with the practical subordinated.

It is impossible that we shall be in complete accord and well it is that we cannot be, for if we were it would be the end of

progress. But if we understand one another, while not traveling together over the same path, we bring our paths so closely together that we can reason together in the gentle tones of friendship instead of forcing our paths so far apart that we shout at each other, and our mutual understanding is only partial.

Your problems are not so vital to us because your materials are lumens and millilamberts and other things that are far beyond our ken, but our problems are vital to you because they deal with glass and brass and other things without which your lumens will not behave as you would have them do.

Before we tell you the things that we hope you will do for us directly we crave the privilege of asking you to know a class of manufacturers who are essential to our mutual success in giving our clients the best there is in lighting. Therefore we ask you first to know the glass manufacturer. In our association with you we find that many times you are weak in this respect and our knowledge not being any too strong your problem is not solved as it should be and our paths start to diverge. Every engineer should familiarize himself with certain fundamentals of the glass making industry. Have you ever seen a glass globe blown? If you haven't, by all means do so, and you will marvel at what glass blowers do rather than grumble at what they fail to do. A little time given to it will soon tell you whether your plan can best be executed in blown, pressed or bent glass. It will show you in a general way just what the manufacturer can do with each type and what his manufacturing costs are. To illustrate: A mould for a 16-inch bowl costs to-day between three and four hundred dollars. Merely because you have a piece of glass that was produced in Bohemia before the war is no guarantee that there has been demand enough for it here to develop the labor to produce it or to guarantee a profit if manufactured. You were perhaps much surprised to learn soon after the outbreak of the world war that there was not a single prism, such as are used on lighting fixtures, made in this country. There was much criticism of the manufacturer because of this. The answer was simple. They were unable to meet the competition and had therefore turned their efforts toward making profitable things.

You may determine by scientific research that a piece of four cased glass of blue, pink, purple, and amber layers will give you

much desired results. Would you not save yourself much if you knew some of the elementary principles of glass making? Glass, you know, is a peculiar thing that feeds on contractions, expansions and other things that may cause its sudden demise when least expected.

In this, I am only suggesting that you do what every manufacturer must do if he would be successful and that is, become familiar with his raw materials. We must know all the idiosyncrasies of brass, bronze and all the other metals we use. If we did not we could not last, but would soon be laid away in that business cemetery, the entrance of which is marked with the doleful motto: "They lie here because of misdirected effort." The path of the engineer who has these facts at his command does not lie very far from ours; indeed we are within comfortable speaking distance.

We have suggested what you could do for us indirectly. Now we will try and indicate some of the things that are of vital interest to us. Again I am going to repeat our theme, "Know us," not only personally, but as a business. Know what we can do for you and in knowing that you will work miracles for us.

In a recent friendly group conversation at which one of your directors was present the remark was made in the spirit of banter that an illuminating engineer was the last man a fixture manufacturer wanted to see come into his showrooms. I am willing to confess that there is a bit of truth in the remark. It ought not to be so, but our paths are too far apart and we are yelling at each other. You ask what are the underlying causes of this remark. We answer that you do not know our limitations. You are filled with the enthusiasm of a brilliant idea and its proper execution means so much to you. It seems the simplest thing in the world to transfer it to metal. It might be simple, but the chances are that it is not. You present your problems to our sales department and in their desire to render you every service possible they agree to help you. The manufacturing department in a spirit of co-operation accepts the order and then the fun begins. As an illustration, let us use our mutual friend the candle. You have a client, and in the course of your negotiations with him you learn that you can please him by getting indirect light from a candle fixture. If you do not know our limitations you

think it is the simplest thing in the world to just slip a little reflector under the silk shade and presto! the trick is done in a few minutes. Just examine the process of development of this fixture. First, a full size working drawing must be made, showing not only the full construction of the candle but of the entire fixture, as a permanent record. This drawing then goes to the factory superintendent who calls in the purchasing department for the silk shade. The shade manufacturer is consulted, he in turn consults the frame maker and in sixty days time a shade is received at a price for which you could buy a dozen regular numbers, and if you are extraordinarily lucky it fits. In the meantime the superintendent has to turn up a chuck to spin a neck to fasten the reflector to the candle, thus throwing this department out of its stride. The same may happen in the arm department and eventually after every one has forgotten what we started out to do we have produced at the cost of fifty dollars, a fixture for which it would seem like highway robbery to charge five dollars. Finally there is the danger that the client has changed his mind and has decided to use something entirely different. In the meantime, the engineer insists that the snail is a futurity winner by comparison and that he will never do business with this particular fixture manufacturer again, and that his client knows that he has fallen into the hands of merciless highwaymen. The unfortunate manufacturer is lucky if he gets his money out of the deal, to say nothing of having made two enemies.

Know your material, and if you are not sure of it consult a reliable manufacturer before you make your suggestion. Know just what we will have to do, what it means to us in time and money. Then we can work together for a result that will be pleasing to your client and we will have done something that will be creditable and add to our future worth to the industry.

Another illustration: Recently there appeared in the *Saturday Evening Post* an article by Floyd Parsons under the title of "Everybody's Business," filled with interesting data and instructive information. But he entirely forgot that the fixture manufacturer existed. In writing of theatre illumination he said the highest efficiency and the best psychological effects can only be obtained when the architect, the interior decorator and the illuminating engineer co-operate. He may have omitted the manu-

facturer for fear of having too many experts on the job and then making everybody's business nobody's business; but in this connection I must call your attention to a theatre that did not forget the manufacturer in its preliminary work, namely, "The Strand." Most inefficient from the scientific standpoint, but most efficient when measured by Mr. Parsons' standards. There is never a day that we are not co-operating with some architect or decorator in the solution of some problem of illumination. When the problems are fully and freely discussed the best results are obtained. Therefore, may we suggest a plan for the next building that comes to you for lighting. First determine what manufacturer you desire to work with you, bring the owner or architect in contact with him and you three work together from the very beginning. The results will be a pleasant surprise; there will be less delays, less misunderstandings and perfect results at less cost. We are more than satisfied to leave the science of lighting to you but for results we must have the freedom that our knowledge entitles us to in producing the fixtures.

There is another vital factor in keeping our paths far apart and that is the tendency of some engineers to furnish their own fixtures designs. For the love of all that is good in illumination don't design your own fixtures. We fully realize that the purpose intended is that of equalizing competition, but does the end justify the means? We don't think so. Every manufacturer has designers who have given their life to the work, who know not only designing but a great deal about fixture construction, the materials available and above all have some conception of how a suggestion on paper will look when produced in metal. Every manufacturer has models, dies and patterns that have stood the test of criticism and from which many thousand fixtures can be produced. Surely there is something in that vast accumulation that will meet the engineer's requirements.

Know your materials; become familiar with what we have and can do. Our products are your tools.

I am glad to tell you, however, that our paths are rapidly approaching in respect to designs. The number of architects and illuminating engineers who present us with their own designs is growing less each year. There is a very marked hesitancy on our parts to estimate on such designs because of the unsatisfactory

results that are obtained too frequently for the reputation of us all. We are looking forward to the day when you know us so well that you will freely use the things that have proven their worth and not ask us to make fixtures that may be of doubtful results.

Gentlemen, there is a very important thing that you can do for us in writing your specifications. Be explicit. If you have by test proven beyond any doubt that a certain device will give you the results you want, why won't you say so?

An incident illustrating what I mean came to my attention recently. A manufacturer with whom I was consulting told me of a set of specifications that he wrestled with for considerable time to find out just what was wanted and eventually discovered that a Frink reflector was the only thing that would fill the requirements. Why not call a spade a spade? The thought that there might be some ulterior motive in your telling us exactly what you need belongs to the dead past. We are just as anxious to give you what you want as you are to have it. It saves your time and ours and furthermore places the responsibility where it belongs; that is, on the specified article. One of the surest ways of getting results is to definitely place responsibility where it belongs. What is everybody's business is nobody's business just as surely in science as in politics.

There is another problem that you can help us solve that is of much concern to us both. It has to do with the general appearance of completed work. It is this: the proper installation of the wiring and outlets. Happily this trouble is never met with when a competent illuminating engineer is connected with the contract. It is often found when the installation is made by a fellow who possesses a pair of cutting pliers, a roll of wire and unlimited nerve. The problem is how to reach these fellows and inculcate in them the pride of work well done. It might be done by a joint publicity committee or by some other indirect method. We feel that as engineers and scientists you could do a great deal in this respect because the contractor does not feel that you have anything direct at stake and are not imbued with selfish motives. We would gladly follow your lead in some such movement.

We have been suggesting helps in the abstract. In conclusion we have something to suggest that is definite and concrete. Give

us a code by which we may be guided. You have determined that a certain number of foot-candles are required for a living room, but where can we find the information for a new man whom we are training? You will tell us that a certain tone of light is best for a dining room but where can we find this information? We know that it has all been printed in your TRANSACTIONS, but it is impossible for us to stop and dig it out. We have a code to go by in wiring our fixtures; why not for the distribution of light? If you will appoint a committee to codify your data and give it to us in a definite and concrete form we will gladly co-operate. We believe such a code would become a standard for the United States and bring great credit to your Society.

All of these suggestions that we have made we beg of you accept in the spirit of co-operation. We want you to know us and shall be glad to have you tell us in what things we fail in understanding you, that we may work together for the advancement of respective endeavors. I have not amplified to any extent the thoughts I have expressed for fear of wearying you, but I sincerely hope that you will give them serious thought. You have done a splendid thing in arranging this joint meeting. It has given us an opportunity to talk together free from the restraint of business and meet as man to man.

In the name of the New York Division of the National Council of Lighting Fixture Manufacturers, I thank you for the privilege you have granted us to appear before you and tell you something of our problems, knowing that they have reached sympathetic ears. May this meeting be the beginning of many friendships that will mean closer co-operation between us. Gentlemen, again we thank you.

DISCUSSION.

CHAIRMAN: In his paper, "What can the Illuminating Engineer do for the Fixture Manufacturer?" Mr. McCoy brought before us a very definite program from a very simple, concise point of view. I would be very glad if we might discuss some of the problems that he brought out.

It certainly is a great pleasure for me to have so many practical fixture men here this evening to have the opportunity to discuss some of these common problems with them and to see if we

cannot, as a result of this meeting, get something started towards practical and permanent co-operation.

Co-ordination should be possible. It seems to me that if we as illuminating engineers can present ideal standards—as we see them, in general relation to color, tone, quality and brightness and so on to specific conditions, and in such a form as to be applicable to the commercial design of fixtures and if the fixture manufacturer can put the suggestions into effect, then we as engineers will accomplish something and you as manufacturers will accomplish something. It seems to me that no matter how far apart we may be in our theory and practice, fundamentally we can get together with the public's need as our common denominator.

Mr. Macbeth: In the discussion of Mr. McCoy's paper, Mr. Cassidy asks for a code on residence lighting. The Society has published a code on factory lighting. Codes infer a reasonable standardization. I can see possible standardization in factories, not only in lighting but in shop clothing—overalls and overallettes—and incline to the belief that we can progress about as far in the standardization of residence lighting as you would in establishing standards of woman's wear in the home—house dresses for work, and kitchen lighting, possibly the laundry and furnace room, but not the dining room and reception room where tastes, rather than rules, will govern.

The fixture manufacturer, if I understand Mr. McCoy, tells the illuminating engineer, "Whatever you do, don't attempt to design your own fixtures—that is art. You know it not, and have lived too much of your life away from those places where art is always ART. You are too late to begin."

My conclusion is that this advice is good, but that it can also be reversed. Mr. Fixture Designer, when you attempt to harmonize the brightness of surfaces, to avoid glare, to eliminate uncomfortable contrasts, to provide adequate illumination for the purposes desired, take up your problem with an engineer of experience before your designs have gone beyond recall. You can always secure as much free advice and consultation time as you are willing to give in design service to the engineer, so that

the cost of this kind of service is not an unknown quantity by any means.

MR. PLAUT: I think the important point that has been demonstrated by our meeting this evening, is the fact that the engineer and the manufacturer have not come close enough together in the past. A meeting of this sort should be a quarterly not an annual event. The engineer and the fixture manufacturer should co-operate more extensively, each are very necessary in the common field. All the illuminating engineers in the world cannot function without the fixture manufacturer, for then we would have to depend upon the bare lamp. Much good can be accomplished through meetings of this sort, and the more frequently they are held the better for our mutual understanding. The fixture manufacturers are largely to blame for their lack of interest in the work of the engineers in the past. We have not co-operated with engineers or among ourselves but now, for the first time in the history of the industry, we have a national organization and through this organization we are going to not only co-operate, but establish a code of business ethics, a standard system of cost-accounting, and standardize wherever possible.

Some of the discussion this evening was quite beyond the comprehension of a layman, and that is how a fixture manufacturer must be viewed in comparison with the advanced standards of the Illuminating Engineering Society. Many of the most prominent executives among fixture manufacturers readily admit the need of closer acquaintance with the elements of lighting and technical terminology applying thereto. At the present time, we fixture manufacturers are not able to absorb the highly technical data which is often prepared for us, and we therefore ask that you deal gently with us at first, giving us only the elementary until we are advanced sufficiently to absorb the more technical data.

MR. DOWS: I would like to say a word from the standpoint of the incandescent lamp manufacturer. It has always been our aim to co-operate with reflector and fixture manufacturers along any lines having to do with good lighting. One long step which we have recently made has been the development of the foot-candle meter. This device makes it easily possible to measure

directly the illumination intensity in any position and has done much to simplify the term "Foot-candle" to the illuminating engineer and reflector manufacturer alike.

Engineering and technical publications by the map manufacturers dealing with the fundamentals of illumination and giving codes for proper illumination for various industries are available to all.

Mr. Anderson: The individual user of light is to be reckoned with, but more from the maintenance standpoint. I recall a factory installation made by a lighting engineer, which was supposed to be most desirable and efficient, and it was—as installed. But as the lamps began to need replacement, the workmen would use almost any kind for renewal. So the installation did not long remain ideal. We also found that it did not suit every individual workman. Some required greater intensities. Much of the good lighting that we are trying to establish would depend largely on the individual requirements. A fixture, with the proper requirements as conceived by an illuminating engineer might not meet with the taste of the owner of a private house. The average woman regards the lighting fixture in the house entirely from an artistic standpoint, its appearance, and its location, irrespective of its function as an ideal lighting medium. People who use fixtures in their homes have to be educated to know what is ideal and this is a very big problem.

Mr Marks (Communicated): If the fixture designer and the lighting engineer would get together oftener the art of lighting, especially home lighting, would undoubtedly advance much more rapidly than has been the case in the past. The fixture manufacturer has it within his power to educate the public in many ways, and, in particular, in the matter of glare reduction. Some fixture manufacturers have taken the position that it is not up to them to educate the public, that their business is to give the public what it wants, whether this be good or bad, provided the public is willing to pay the price. Other manufacturers of a better type have cautioned the public against the use of glaring lights and have made an honest effort to design and sell lighting fixtures that combine both artistic and scientific illumination. There is

no doubt whatever in my mind that the better type of fixture manufacturers will win out; there is evidence on every hand that the public is being educated very rapidly to appreciate what is intrinsically good in lighting fixtures. In this campaign of education the Illuminating Engineering Society has played a most important part. However, notwithstanding the progress that has been made, only the surface has as yet been scratched. There is room for great development and vastly wider operation of the lighting art; this development and lighting application will come about sooner if the fixture manufacturer and the lighting engineer get closer together and combine their efforts to give the public the right thing.

Mr. Stickney (Communicated): Having read Mr. McCoy's excellent paper, let me discuss the relations of the Illuminating Engineering Society to an association of fixture manufacturers. I am doing this with the hope of clearing up some misconceptions regarding the Illuminating Engineering Society.

I think the viewpoint expressed by Mr. McCoy, is representative of that generally held by lighting people, who have not seen the inner workings of the Illuminating Engineering Society. I believe my viewpoint is typical of the active members of the Society, although I am not speaking officially.

As a background, let me first portray the Association of Fixture Manufacturers. It appears to be an association of business interests, for the study of all sorts of vital problems—commercial, manufacturing, engineering, artistic. But of necessity, as with any other business association, its fundamental purpose must be the advancement of a particular line of business. This is a necessary and laudable purpose, which has received a broad and high grade treatment by other lighting associations in the central station business, the gas business, the contracting business, the lamp business, etc. Nevertheless, such organizations have certain limitations, due to their commercial relation and the presumption of prejudice therefrom, even though the prejudice may not actually exist.

Now, let us look at the Illuminating Engineering Society. First, note that it is not a society of engineers, as it is sometimes considered. Engineering rather expresses its purpose than its

composition, and in this connection, engineering should be considered in its broadest sense, so to include the engineering of fine art as well as that of practical utility. The fixture manufacturer, the decorator, the architect, are as properly members of the Society as the lamp engineer, the central station expert, the consulting engineer, the medical man, or the light user himself.

In my conception of the Society, all those that have to do with the production, moulding or application of light, should get together through this organization, strip off the camouflage of commercial interest, and determine and disseminate the facts and best conclusions regarding light and lighting.

It is true that members of the Society are associated with business interests, but in selecting officers, committeemen, etc., commercial interest has been balanced out, so far as possible. The user's viewpoint, protects against prejudice in favor of the producer, the gas man meets the electric, etc. Activity on the part of fixture manufacturers can readily meet any opposing interest. If all co-operate, the result is fairness and truth. That this has been attained to a remarkable degree, is evidenced by the acceptance of the Society's recommendations as the basis of legislation by so many governmental bodies. So impartial has been the attitude of the Society that its work has not been recognized as advantageous by many of the commercial interests of the lighting business, whereas, in reality, the Society renders an unusually valuable service to the lighting industry, which is very much strengthened by its disinterestedness.

When the Society was first formed, the greatest need was for a better knowledge of the mathematical and other scientific principles of light applied to equipment and installations. It is not surprising that some of the early work tended too far to that extreme. I believe that tendency has been largely overcome, though the membership undoubtedly is drawn more largely from those skilled in meeting utilitarian demands than from lighting artists, and individual expression of the efficiency viewpoint will still be found in the TRANSACTIONS. The cure seems to be for the artistic group to take more active interest in the organization, bringing it to the happy mean.

I am sure they will be benefited, since we still see beautiful fixtures put out, which unnecessarily fail to produce useful and sometimes artistic lighting effects.

Therefore, let us accept Mr. McCoy's invitation to know the fixture manufacturers, and may it be in part as equal members of this Society, sincerely working on our own common problems.

MR. McCOY: I think that the most important suggestion in my paper is the paragraph in which I suggest a code by which lighting fixture manufacturers may interpret what the illuminating engineer desires; I have discussed that with some members of the Illuminating Engineering Society and they rather insisted that it was impractical and impossible. To me it is a perfectly definite thing that is worth discussion, and, if it is possible, I think, would do a great deal toward bringing together the illuminating engineer and the fixture designer.

ARTIFICIAL LIGHTS AND THEIR FIXTURES IN JAPAN.*

BY MOTOO UCHISAKA.

I. INTRODUCTION.

The nature of artificial illumination is determined as a matter of course by the kinds of light sources and lighting fixtures available. Therefore, the development of the latter implies that of the former, and vicé versa. And if there is anything that can represent the human progress in a definite and concrete way, artificial illumination is certainly the one. It shortens night and prolongs day, conquering darkness at every turn. It is the quintessence of civilization, for civilization is ultimately a series of victories over nature. Japan is one of the oldest countries in the world, and has its own history of illumination as well as civilization. Thus, some brief account of artificial lights and their fixtures, may be of interest to those who care to trace the past fortunes of mankind at large, especially to those who would like to know something about Japan.

Japan seems, as it were, a museum of Oriental Civilization, for civilization in Korea, China and India was all introduced into Japan. This was renovated, developed, and stored, to the advantage of the island empire, by this age of excavation and archaeology. Consequently there was a large variety of artificial lights and their fixtures introduced from abroad as well as developed at home. Some typical examples will be shown later on.

But Japan was a later comer to the world of new enlightenment, and was dazzled with the brilliance of civilization of the West. About sixty years ago petroleum lamps were first introduced into Japan. Soon after came gas lamps then electric lamps, and now it has come to pass that Japan is able to manufacture various sorts of incandescent lamps, in fact, more than enough for domestic consumption. To-day there is hardly any place throughout the empire, where electric and gas lamps are not used. Modern Japan was only half a century in the making, and the undeveloped economic conditions of the nation were not favorable to such rapid assimilation of this new civilization. The

* Paper presented before the joint meeting of the Society of Gas Engineering of New York City, and the New York Section of the Illuminating Engineering Society, February 19, 1920.

difference between the cost of living and earnings in Japan and those in the West before the Great War was very great, while the charges for electric or gas lamps were approximately equal in the two. In other words, the proportion of the cost of illumination to that of living in Japan was far larger than in America and Europe. This was why the modern way of illumination was not developed so well as the rest of new appliances in Japan. Now things are going to change rapidly after the war.

For the past ten years and more, I have been doing my best in spreading the knowledge of illumination as well as encouraging the use of lamps of high candle-power among my fellow country men. I devoted myself at the same time to the study of the history of artificial illumination in old Japan with the result which is embodied in my recent book entitled "History of Artificial Light in Japan." What I have to describe here is a sort of extract from the above work; and I trust that it will give the general public, besides the professionals in the West, some illustrations of the progress of illumination in Japan, and render service, be it ever so little, in introducing the better understanding, which is but another name for true friendship, between the East and the West.

II. Civilization in Japan.

A brief sketch of the history of civilization in Japan, at the outset, will no doubt be useful as well as necessary, for it will not only facilitate the understanding of the subject in hand, but will also afford an excellent opportunity of introducing Occidentals to a glimpse into the otherwise unknown past of Japan and her people.

The foundress of the Japanese Empire was *Amaterasu-Okami* or "the great personage who illuminates the world from on high," a name not without some suggestion to the present subject. The mythological records of seven reigns before her abound with interesting stories which however have little value for historical purposes. There does not exist any positive evidence for deciding from where *Amaterasu-Okami* came to Japan. Only suppositions are made that she came from the South. She was the progenitress of the people as well as the Imperial family of Japan.

It is ascertained by relics that the civilization in the time of *Amaterasu-Okami* was far more advanced than is generally supposed. Arts of agriculture, sericulture, weaving, metallurgy and pottery were already known. Clothing consisted of coat, skirt, and other articles; a crown was put on; and jewelry was worn as the most valuable decoration. Houses were constructed with pillars, and provided with doors; floors were covered with mats. People wore swords, used bows and arrows, bred horses, brewed wine, and had rudimentary knowledge of shipbuilding and navigation. They composed poems and played music, some of which are still remaining. Their finicality in matters of cleanliness was most conspicuous. It was the root of all their curious customs. They built each time a lying-in-hut for birth, a funeral hut for burial service, and a hut whenever marriage or reception of the dignitary took place. In short, cleanliness and freshness were essentials in their life. The same reason accounts for the fact that they used to wear garments in white over red garments, and despised such colors as blue, black and others as mean and filthy.

Five dynasties after *Amaterasu-Okami* were occupied in exploiting the land. The sixth in descent was created the first Emperor of Japan. He was *Jimmu* in posthumous name. The year of his accession fell in 661 before Christ.

In 32 B.C., in the reign of *Sujin*, the tenth Emperor, the intercourse with Korea was opened for the first time. Thereupon Japan was admitted to the benefits of civilization, and improved her condition with the assistance of scholars and artists invited from Korea. Civilization in China was also introduced through Korea gradually.

Buddhism was introduced into Japan in 545 A.D., and it did to Japan at that time what it and other great religions did to nations in their early ages. Since then Japan has made rapid strides in her progress, for the introduction of Buddhism was soon followed by direct intercourse with China, which was then at the pinacle of glory under the rule of the T'ang dynasty. The influence of unparalleled civilization of the T'ang dynasty upon Japan was most remarkable, and held sway over her from the very beginning of the dynasty in 641 till its fall in 809. It was in these times that the nation entered the civilized life in

its true sense and laid the foundation for development in after periods.

The next period, 810-1339, witnessed the assimilation or nationalization of these alien elements of civilization introduced in the preceding period. Civilization hitherto connected with, or embodied in Buddhistic institutions had a tendency to become more general in its scope and independent in its function as the time went on. In architecture, in paintings, and in upholstery, evidences are quite obvious in these days.

Then came the period, 1340-1595, which might be called the golden age of fine arts in Japan. Great works of art were produced in countless numbers, many of which are now preserved as national treasures and rank among the highest in the world. Genius of the nation was revealed perfectly everywhere in the field of art, not only fine but also useful. But the achievements of this period bore the stamp of aristocracy, for they were made in response to the requirement of feudal lords, and their characteristic was the predominance of splendour.

The excessive splendour in the last period disappeared in the next, 1596-1867, and was replaced by popularity, for the common people who were excluded utterly from the political circles under the *Tokugawa* Government, and thrived in commerce and industry soon found access to the higher products of the day, and their influence was inevitable. New and original schools in art, literature, music etc., cropped up like mushrooms after the rain, and gave full swing to plebian taste.

Indeed, this was the so-called *Yedo* civilization of the plebians. It flourished for two centuries and more and fell with the old system of feudalism.

In the *Meiji* era, 1868-1911, Japan was busy again with introduction of civilization from abroad. In the former period Japan had closed her ports to all foreign ships except a few from Holland in addition to those from China and Korea. But the coming of Commodore Perry's squadron forced Japan to open her doors; and she at once recognized her situation in the world. Japan must at any rate be reconstructed after the model of the Western countries in order to come up with them, and the work admitted of no delay. This was one condition. And the other

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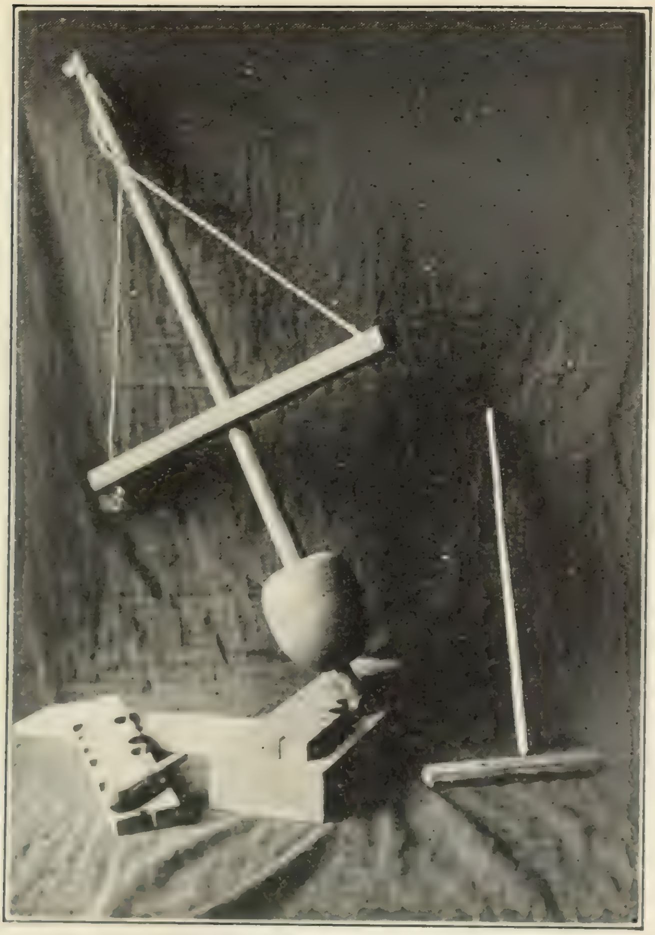

Fig. 1.—Primitive method of producing fire.

Fig. 2.—Tinder box with compartment for the flint and steel as well as the combustible material

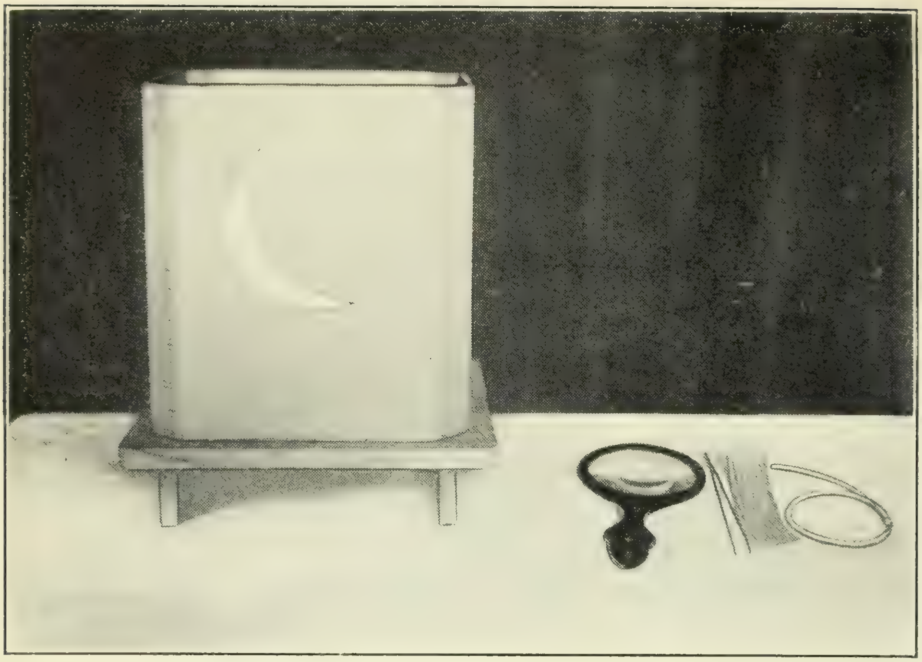

Fig. 3.—Equipment used for producing fire by utilizing the sun's rays.

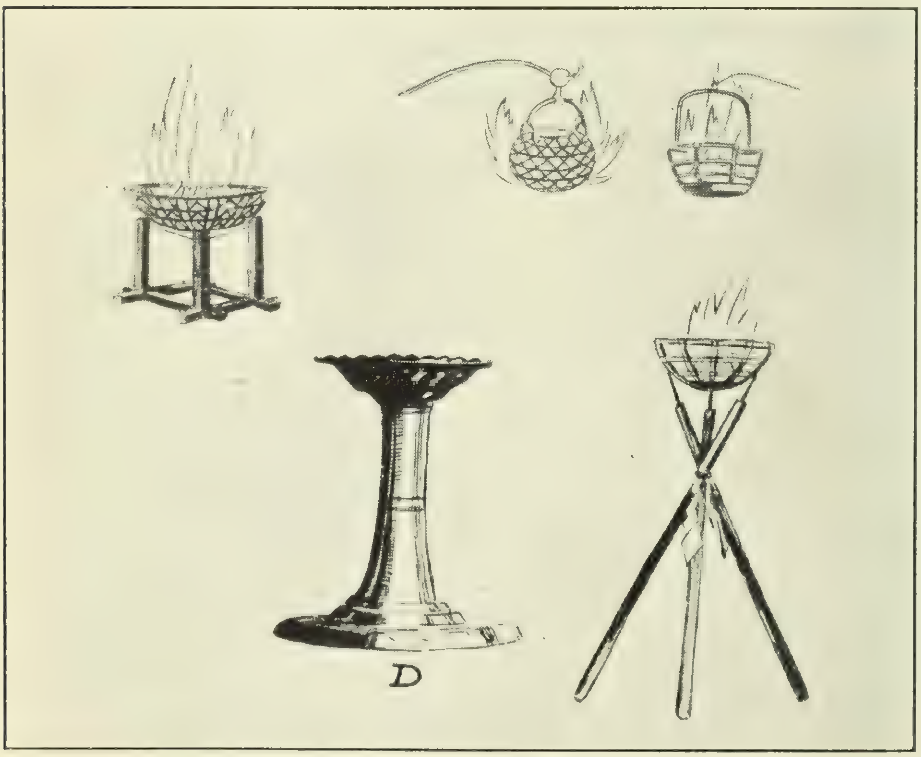

Fig. 4.—Basket and stand such as shown above were utilized when wood-fires were the illuminus.

was that the *Yedo* civilization was carried too far, while the whole nation was already seeking after some new form of development. If, therefore, there was any country awaiting the American mission of enlightment, Japan was the one. It was no wonder then that the making of modern Japan brought with it the introduction of civilization in the gross, and that everything Western was taken eagerly irrespective of its being fit or not for the conditions of the country.

Quite recently however, there appeared some signs of deliberation as to the real demands of the people, according to which the choice among the things Western should be made with prudence. Modernization of the products in the old times was also initiated on repeated suggestions made by the lovers of Japan from abroad. With the commencement of the present *Taisho* era in 1912, Japan once more awoke to the full sense of responsibility for the fulfilment of her part in the advancing of the world's civilization to which, it is expected, such movement as here instanced might render some service in the near future.

III. Light Sources and Lighting Fixtures.

IGNITORS.

The most primitive method of producing fire in Japan was the friction of two woods of the *hi-no-ki* or Japanese cypress. It was improved somewhat later by introducing some mechanical powers in such way as shown in the centre of Fig. 1. But ignitors of this sort would require much effort in their operation if kept, while they would lack portability if made more effective. So they were subjected to inconvenience anyway.

Still later the concussion of flint and steel was introduced for the purpose, and continued to be used until very recent times when modern matches appeared. Fig. 2 shows a tinder box which contains a flint and a steel in one partition of it, and combustible material in another. This material, consisting of tinder or charcoal powder, catches the fire as it is generated, and transmits it to a slice of some inflamable wood, one end of which was sometimes covered with sulphur. After the fire is thus transmitted, the lid is let fall, thus putting out the original fire in the box. These ignitors being small and portable were

highly valued and often put into bags of various shapes. Match-cords were also carried in cases when there was need of keeping the fire on the way.

Also it is recorded in history that about eleven hundred years ago a Buddhist sect used to produce fire by concentrating the rays of the sun on a chip of wood with a convex glass lens with the view of getting pure fire from heaven. Fig. 3.

WOOD FIRES.

The wood fire in its beginning was simply built on some combustible wood such as pines; consequently there are few remains to be seen in these days. It was not portable in its nature, and was burned mostly on a fixed place which was originally open but afterwards a partition was made for the protection against wind and rain. But in later times the fire was lighted in an earthen or wooden vessel in which soil or ashes were laid, and still later in an iron basket which was hung by a chain from the ceiling or the wall, or set up with props on the floor (Fig. 4).

TORCHES.

The *tai-matsu* or torches are as old as wood fires. They were in the beginning made of resinous heartwood of pines, or of cedars, Japanese cypresses, bamboos, or their barks, split and tied in a bundle of portable length and thickness. Sometimes they were made very large and planted and lighted in the garden for illumination. In another time, portable torches were bound three into one, the legs of which were stretched so as to stand safely on the ground, and lighted for the same purpose.

These earlier torches were all for outdoor uses, but later sorts, for indoor uses, were also very serviceable until the time when the *te-shoku* or portable paper-covered candlesticks came into use. The first of the later ones were made of a slender piece of resinous pine, about a foot and a half in length, saturated with oil, chared at one end, and wrapped in paper at the other so as to prevent the hand of the holder from being stained. The second and later were made of paper instead of wood, and the paper was oiled in like manner. They began to be used after the lamp oil was first introduced at about the end of the 12th century and were in a way a forerunner of candles.

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FIG. [illegible].—A typical primitive lamp-stand used for supporting a vessel in which was placed the oil and wick.

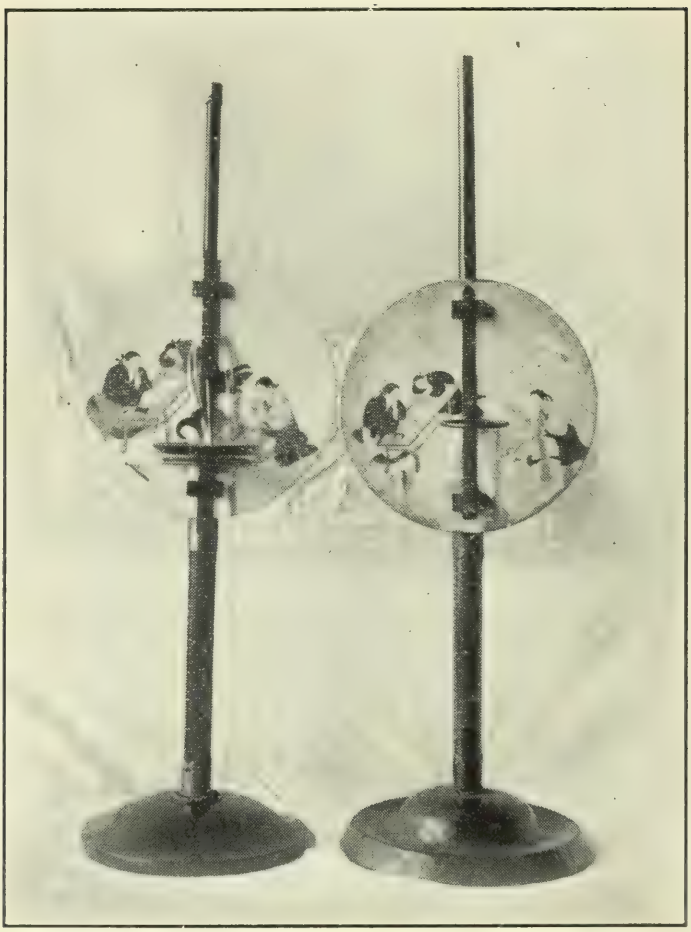

Fig. 6.—A later development of the lamp-stand showing the adoption of a painted board as a reflector. This reflector was usually decorated for artistic effects.

LAMP-STANDS.

Illuminants were improved from wood to oil, and the latter was used from the beginning with the *to-dai* or lamp-stand. But it was burned on a piece of wood in a vessel, shown as D in Fig. 4, for wicks were not yet introduced. The lamp-stand was the kind of lighting fixture that was in use for the longest time, the result of which was to be seen in the great variety of types developed. The main structure consisted of three wooden legs, about two feet and a half in height, which were bound by a string through holes in each leg at the point of intersection. The stretching of the legs was adjusted also by a string at the lower ends Fig. 5. Each held a vessel, earthern or other material, which contained the oil and the wick. But the trouble in the type was that the oil dropped outside the vessel through the wick which extended over the edge of the vessel. The later type was devised by placing another vessel underneath. Besides this, there were some devices employing cloth or oiled paper spread under the bases, while in others the bases were shaped like dishes to receive the drops of oil.

The lamp-stand that is shown in Fig. 6 is one of those that may be regarded as the improved style, from the view-point of the science of illumination. Each had behind the light a round board painted white, gold or silver, and adorned with a picture in colors which had reflecting as well as artistic effects. Some of them had also devices for adjusting the height according to uses. Besides, there were lamp-stands for hanging from the wall and for carrying about.

Another improvement in lamp-stands was made a little later in shading the flame with paper or cloth to protect it against wind. The shade was sometimes adorned with a picture which made the apparatus beautiful in its appearance. It was from this kind of lamp-stands that the *andon*, one of the most popular lights in Japan, was developed in the later period.

BASKET LANTERNS.

The *doro* or basket lanterns may be divided into two classes: namely, the *oki-doro* and the *tsuri-doro*.

The *oki-doro* or standing basket lanterns were chiefly used outdoors and for illuminating gardens or in dedicating Buddhist

temples or *Shinto* shrines. They were arranged in rows in great numbers about the grounds. The materials of which they were made were copper, bronze and iron, the stands often being carved out of stone. In their beginning, they were mostly without stands, which were however brought into consideration after a time, and at first made of wood. They developed at last into objects of artistic appreciation.

Thus, the standing basket lanterns left every variety of styles in their development through the ages. Especially those for gardens were rich in their styles.

Much can not be said about basket lanterns of wood, for there are none remaining, in spite of their certain existence in early times. But it seems that those of wood were generally simple in construction and not elegant in shape in comparison with those of metal or stone. (Fig. 7).

The *tsuri-doro* or hanging basket lanterns were made of wood, copper or iron like the *oki-doro*, and sometimes of bamboos, but not of stone. They were used first in the middle of the 7th century in the Court, later in the high circles, and were regarded as the most important for interior illumination along with the lamp-stands. But, when still later they came to be valued for the purpose of dedication to Buddhistic temples, they began to have religious elements in their form. And of course this tendency was to be seen in standing lanterns as well.

CANDLES.

Candles were manufactured in comparatively recent years though they were anticipated in the old way of torch making as before said. But the torch was quite another thing than the candle; and it was fit for neither lanterns nor candlesticks.

Fig. 8 shows one of the primitive candles which were made of pine resin wrapped in a leaf of the bamboo-grass. There was also another type which was made of a short cut stem of the durra, coated with resin. The latter was in some respect the prototype of the candles with wicks, only undeveloped because the durra remains after the resin burned itself out. Later the durra was replaced by paper or piths of the rush.

It was still later that candles were made of the resin from fruits, lacquer or such trees kneaded and solidified with the oil,

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Fig. 7.—A large type of basket lantern. Large numbers of these were placed about the grounds.

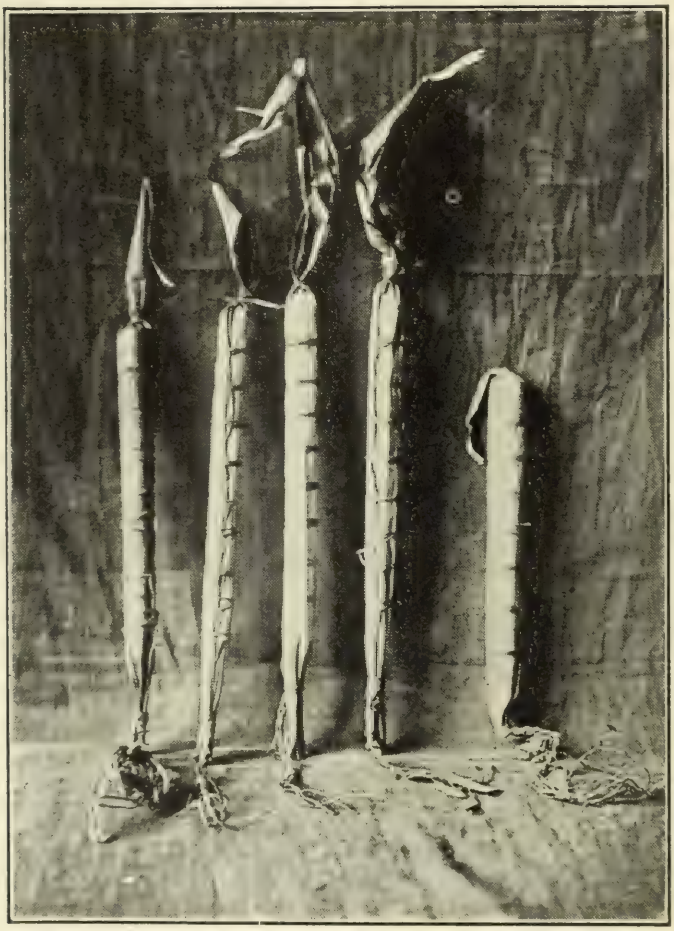

Fig. 8.—Typical primitive candles made of pine resin wrapped in bamboo grass leaves.

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Fig. [illegible]. Portable candlesticks of the floor type. Some of these were doubtless developments of the lamp stand

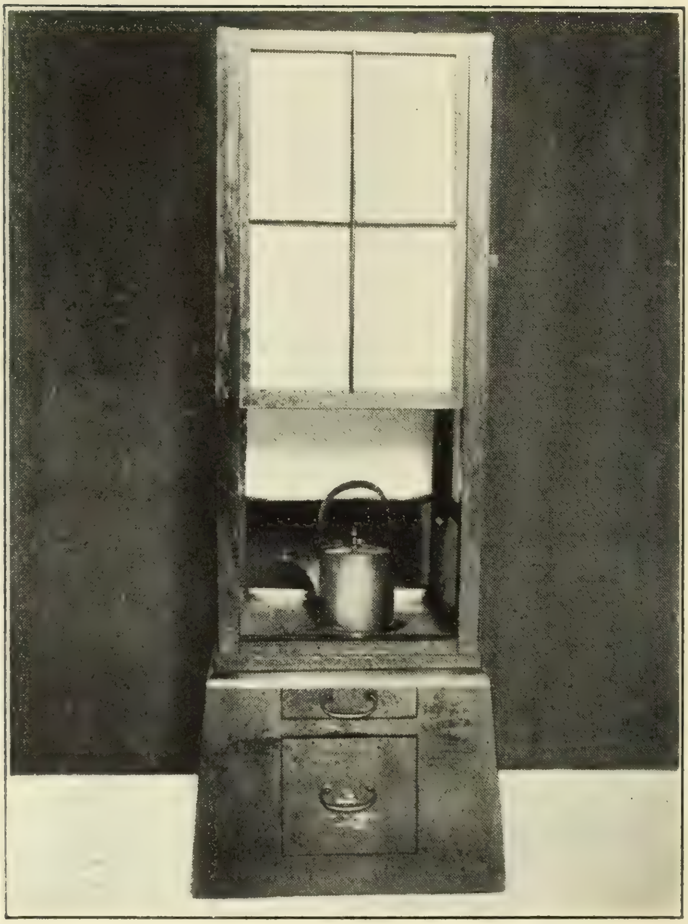

Fig. 10. A typical andon showing the method of protecting the light source from the wind.

and had the wicks of two or three pieces of piths of the rush. Candles of this sort were used until very recently; and they caused a remarkable development in lighting fixtures at large. They were superseded after the intercourse with the West was opened by those of foreign origin which are now generally used in Japan.

CANDLESTICKS, PORTABLE CANDLESTICKS, ANDON.

Candlesticks which were made for holding candles and used for interior illumination were not very ancient in their origin. It is possible that they were transformed from lamp-stands of the former times, seeing that there was little or no difference between the two. Some of them were apparently remade from lamp-stands. Others seem to have been fitted for either candles or oil burners, the latter being still in use when the former appeared. Candlesticks in simple structure were made cheaply; so they were used by all classes of society till modern times.

Candlesticks which were intended for placing on the floor and therefore had some weighty and broad base for stability and were naturally not portable. So the *te-shoku* or portable candlesticks were devised to evade this inconvenience (Fig. 9). Their main structure consisted of a base or bottom with a hand attached to it, both of which were made of bronze or brass, and sometimes of iron or wood.

However, candlesticks of above sorts were all open to further development, for they were provided with nothing in the way of protection against wind, which was especially necessary since Japanese houses were so constructed as to be well ventilated in the summer season. The *andon* or paper-covered lampstands were the natural outcome of times when paper was everything. Therefore the *andon* were in their early years simply another kind of lamp-stand or candlestick shaded with paper; but a large variety of types were later developed. Hand candlesticks were also shaded in like manner, and they were very serviceable till recent years (Fig. 10).

LANTERNS.

The *chochin* or lanterns were the most appreciated of portable lights for outdoor uses, and are still used in the country-side where the streets are not properly illuminated. The earliest

type of these lanterns consisted of a basket twisted with splitted bamboos, wisteria-vines or some such things, and covered with paper, the candle being rested on the bottom. The basket was to be lifted in case of setting light. The lanterns of this sort were not very convenient. But an improvement was soon realized in quite a novel framework which was made with a number of rings of fine bamboo fastened together one upon another leaving some space, so that it might be collapsed between the counter integuments when not in use. The paper which covered the framework was oiled for protection against rain as well as rendering it transparent. Shapes were mostly cylindrical, and often spherical or ellipsoidal.

Lanterns were used for various purposes because they were handy and manageable. They served as the door light, festival decoration and other purposes within or out of doors, as well as the only portable light of great importance; and they are still valued for decorative purposes (Fig. 11).

DARK LANTERNS.

The *gando-jochin* or dark lanterns were devised for throwing light in one direction at night watches, and were a miniature kind of search-light of modern times. Their mechanism consisted of the application of a universal joint formed of two hoops which turn diametrically one on the other on pivots, in a cylindrical tube of metal or wood so as to insure the candle always being in the upright position.

MINERAL OIL, GAS AND ELECTRIC LAMPS.

Mineral oil, gas and electric lamps have undergone few modifications since their introduction into Japan in the middle of the Meiji era. But as their shapes and fittings lacked harmony in a certain degree with the buildings of Japanese style which was preferred to the foreign, the demand for modification of them after the national taste became more and more pressing in proportion to the ever-increasing extent of the use of the new lights. To-day, they are being experimented on in the way of Japanization, and it is hoped that something worthy of the efforts will be developed in the near future (Fig. 12).

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Fig. [illegible].—A lantern of the portable type. This could readily be collapsed as shown when not in use.

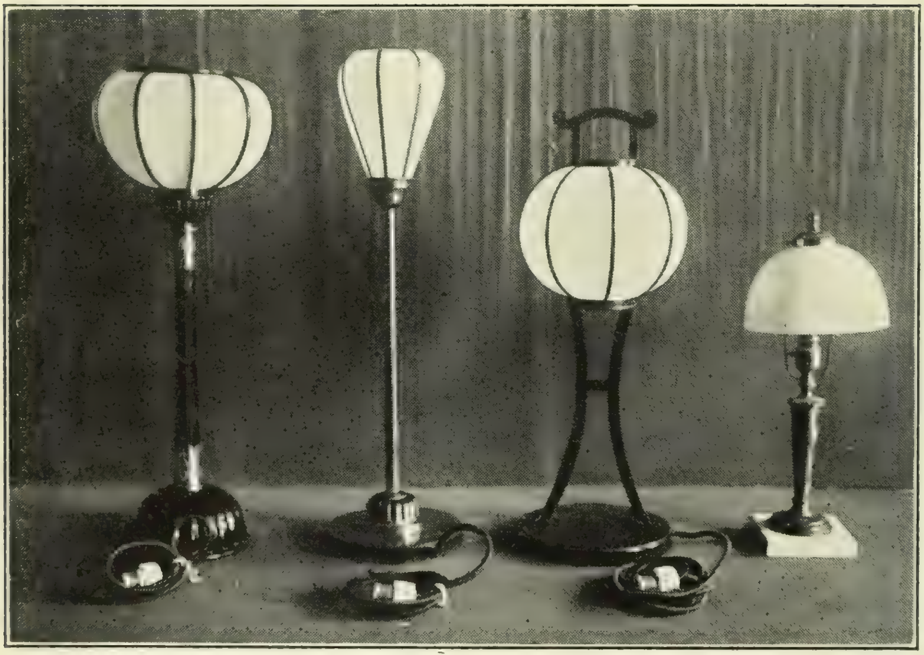

Fig. 12.—Typical examples of the present day electric portables.

IV. Conclusion.

The above account of Japanese artificial lights and their apparatuses is nothing but a rough sketch as to their development in accordance with the general progress of civilization in Japan. But it will answer at least my original intention which was explained at the outset. The rest will be made up by illustrations which are more serviceable than words for such a subject as here treated.

Japan, once a hermit empire in a corner of the great ocean, with all her accumulation of old civilization, introduced first from Korea, then from China, and from India through China, is yet a late comer to the world of modern civilization. The problem of Japan to-day, therefore, is how to make sure of benefits of new enlightenment for the wholesome growth of her national life. But if it is not too much to say that Japan is able not only to digest but also to develop civilization from abroad, not unprecedented in her early days, the task before her will not fail to bring some result which is in essence more cosmopolite than national.

Meanwhile, the recent progress of Japan was prompted and aided by that of senior nations of the West, to which Japan owes in fact all that she is now. Therefore the aspiration of Japan to-day and after is and will be wholly for advancing her noble heritage in the matter of civilization, and by that, making contribution, to the cause of humanity at large. This is also what men of sciences relating to illumination, among whom I am occupying a humble position, and manufacturers of electricity and gas in Japan have in common and hold as the ideal of their effort in their own field of work.

RESIDENCE LIGHTING—AN ABSTRACT.*

BY M. LUCKIESH.

Residence lighting has been the laggard in the march of progress. The attitude of the householder toward lighting has been too purely utilitarian; that is, it is similar to that with which fuel and food are viewed. Considered from the viewpoint of the potentiality of lighting, relatively little progress has been made in lighting the home. Lighting equipment in residences is grossly inadequate but this is due to the general lack of appreciation of what light can accomplish toward making a house a home. One of the fundamental deterrents is the concentration of attention upon fixtures as objects rather than as a means to an end. Lighting effect is the important result and from this broader viewpoint of lighting, many fixtures appear aimless.

The broader viewpoint of lighting can be achieved best by considering light as a medium somewhat akin to those of the decorator. By "spraying" light upon the walls, ceiling, and various objects, certain effects upon the mood or expressiveness of the room are obtained. We can control the direction, distribution, and color of light as desired and by varying these, we can produce effects more positive and powerful than those produced by decorative schemes. And finally in lighting we have the superb quality of mobility which the decorator's media do not possess.

Lighting fixtures have a right to exist as vital sparks of ornament, but in general we should look beyond the fixtures to the effects upon the room. The home is the theatre of life and in it we find many moods and occasions. There is a need for the development of the lighting-artist who, with his depth of vision, artistic sensibility, sound technical knowledge, and demonstration rooms, will reorganize the presentation of lighting to the householder.

In general, lighting *fixtures* are designed, displayed, purchased and installed. This procedure has inhibited the development of an

* Various phases of this subject have been presented before the Sections of the Illuminating Engineering Society: Philadelphia Section (Baltimore), Nov. 21, 1919; New York Section, Dec. 11, 1919; New England Section, Dec. 12, 1919; Philadelphia Section (Washington), March 19, 1920; Chicago Section, April 14, 1920.

appreciation of the potentiality of light on the part of the householder. The fixture dealer (and others) should equip rooms for the purpose of demonstrating lighting effects upon a room. It has been shown that such a procedure awakens the householder to the great possibilities of lighting. When he sees lighting as a powerful factor in affecting the moods of his rooms and in making his house a home, the householder will recognize that the cost of lighting is insignificant. Adequate lighting equipment can do much to overcome monotony in a home. Decorative schemes are "anchored" for years and the householder attempts to escape monotony by rearranging furnishings, by adding a charming new note such as a vase of flowers, etc. But in the mobility of lighting we have a powerful ally, for by the pressure of a switch or two, the lighting may be changed from a quiet restive mood to a flood of light for a joyous company.

Analyses of lighting in various rooms were presented and especial emphasis was given to the deeper psychological effects. It was shown how this general treatment of the subject of lighting the home opens the eyes of the householder to the potentiality of lighting and how his awakened interest results in the installation of adequate lighting equipment. Adequate wiring plans as installed in houses under this broader scheme of the presentation of lighting to the householder were shown.

DISCUSSION.

MR. MURPHY: I think that Mr. Luckiesh is to be congratulated on the wonderful showing which he has made in a constructive sense. We very frequently have heard some beautiful theories exploded with reference to improvement in home lighting without any really constructive criticism being offered, and speaking as a fixture dealer I want to say that I believe that Mr. Luckiesh has ably presented the problem.

MEMBER: I have been perfectly in sympathy with the speaker this evening on a great many of his points. Real home lighting is the lighting of each particular room with a special reference to what that room is to be used for. While I might take issue with him on some points, in general his arguments are practically the same as my own convictions. My effort has been mostly in the larger installations, and there we have made an

effort to get to a point, not of efficiency of light but efficiency of tone, something that is attractive; something that will appeal. The strong light is ideal to attract a crowd and then gradually subdue the illumination to a harmonious color effect which people crave and find restful. That same thought is daily growing more in application to the home. The numerous floor lamps and the elimination of the ceiling fixtures are indications of the general trend. It will take only a few years of educational propaganda by the engineer co-operating with the artist to arrive at a point where we will have more in the way of a pleasant and satisfactory lighting scheme for residences.

MEMBER: I have been very much interested in the talk tonight. It is along a line in which we are making definite progress. We are giving more attention to artistic lighting. We have been a little crude in ways, perhaps our ancestors are responsible for the fact. The original immigration to this country, and even after that for a good many years, was not for the purpose of art although it was to improve the environment, but in general it was from a utilitarian standpoint. As the country developed in wealth we have been able to give more and more attention to the artistic. This is being displayed to the greatest extent in homes, clubs, hotels and similar places where lighting is not wholly utilitarian, and strange to say the artistic consideration is in evidence even in factory lighting. We should recognize that this feature as well as the intensity of the light is an aid to production.

Regarding lighting in the home, an after thought occurs to me in detail, and it is one that Mr. Luckiesh has suggested. We can, of course, have a great variety by changing lights in position and in color, but a short time ago I noted a magazine article devoted largely to interior decoration, something about "Are you neglecting your ceiling?" That is generally a rather broad expanse without very much of a decorative feature. It is true, your eyes are not directed toward it a great deal, but there are times when it can serve a decorative purpose. Now, in addition to a single tint that might be thrown upon the ceiling by a direct or semi-indirect light, it is possible to place a glass over a lamp with a lot of different colors upon it, so we may get a nicely mottled

effect on the ceiling, when so desired. Or, if we admire certain paintings or mural decorations we can use colored lantern slides and project them on to the ceiling. This probably would require considerable expenditure of energy, and perhaps you would not like to do it, but it can be used on special occasions for variety as well as for artistic effect.

MR. ROGERS: Not long ago a very good architect designed a house for me and everything was first-class so far as the architect's design was concerned, excepting when it came to the last line of the specifications on the building. The last line read: "The fixtures will cost fifty-five dollars." Now, it is needless to say that the reason that he put it in that way was that he wanted to make the house cost a certain amount, and that is all the money he had left, but the balance, of course, was among the "extras."

This lack of appreciation of lighting by the architect I understand is quite general but I wish it were not so.

MR. ARENBERG: I think that perhaps one of the best suggestions that Mr. Luckiesh offered is that to the fixture dealer, that he have at least one room of his group of display rooms, showing only one fixture. In other words, selling lighting effect rather than fixtures.

MR. GRAVES: In making our lighting survey in Chicago we found in a great many homes that we visited that an effort had been made to beautify and improve the lighting equipment. The methods used were varied, indeed. The silk handkerchief over the hall or the living room fixture was perhaps the most common to subdue the bright light, and give color. The shawl effects over their tables and floor lamps were frequently found. Perhaps the most effective were the silk bag effects with a tassel at the bottom, hung around the semi-indirect bowls. This was a successful attempt to get away from the cold or glaring cheap light opal or C. R. I. glassware. In general, it seemed to be the tendency to sacrifice illumination efficiency to beauty.

MR. LUCKIESH: Let us consider for a moment that old type of fixture, the dome for the lighting of the dining room table. It was an obtrusive unit, but it lighted the dining-room table in

general better than it has been lighted since. But it went out of style. We got tired of it for two reasons. First, because we get tired of anything after we have to look at it long enough. Secondly, it was a large affair; it had to be hung low; and therefore was very obtrusive by its position.

Let's see how far the designer of fixtures missed it. If he had taken a vote from people who have studied the matter I think he would have found that he had designed nothing that was better than that dome, or anything as good. He forgot to distinguish between lighting principles and lighting fixtures, and after he cast aside the dome he took another dome and turned it the other side up, giving us a lighting effect which was quite the reverse of the effect that everybody would have agreed was good. Then we have the people who adhere to the traditions of Art. We all admire some things of the past centuries. They were wonderful fixtures, fine objects to look at to-day. But there comes a time when we must sacrifice Art. We have no place to-day for the beautiful crystalline chandeliers of certain past centuries in France. Designed for candles, the goregous effects from these lighting fixtures can readily be imagined. But if we must copy fixtures, let us copy them only as long as they are in keeping with our requirements and with the lighting sources in use at the present time.

Mr. Doane: I feel that there is little which I can add in connection with this subject, for Mr. Luckiesh has specialized on it for years.

But I do wish to mention this point. Most of the older engineering professions have associated with them a class of mechanics or workmen who can execute the plans as prepared by the engineers. These journeymen perform the tasks of application. In illuminating engineering we have had no such journeymen. As a consequence the illuminating engineer cannot lay out his work in terms of illumination to be provided because no workmen are prepared to handle jobs on this basis, and he has been compelled therefore to devote much of his time to specifying just how the installation should be made which could otherwise have been devoted to better advantage in studying the peculiar requirements to be met.

The Illuminating Engineering Society has been attempting to educate the men who actually install the systems of lighting to regard this work from the standpoint of lighting, not merely wiring.

But it is only in the last year or two that we have been able, through the development of a clever idea originated by Dr. Sharp, to put into the hands of the average wireman a tool which enables him to get a practical working knowledge of intensities of illumination. The foot-candle meter now makes it possible for us to talk to him in terms of light on the work and after educating him relative to the quantity of light for different classes of work we can talk to him on the control of direction to eliminate glare and soften shadows, the color, and other details.

I believe that the educational campaign which our Society is putting on is going to produce the desired results and that we will develop a group of men who can be relied upon to install lighting in accordance with proper engineering standards. I think we are seeing the last of lighting layouts in terms of sockets.

MR. HARRINGTON: I should like to ask Mr. Luckeish regarding his recommendations on wall brackets in the living room.

MR. SINCLAIR: I am one of those contractors who resent the implication that we are indifferent in advising our customers regarding proper illumination, to illustrate: A client desires to build a house costing ten thousand dollars. He asks the electrical contractor to estimate on the wiring, which may be five hundred dollars, but by the time the subject of lighting is reached, his cost has been over ten thousand dollars, possibly twelve thousand dollars, so he is looking for a place to cut, and decides that three hundred dollars is enough for wiring, and fixtures are usually regarded in the same way. So you can see that in the average case the final results to all concerned are very poor.

My policy has been entirely different. I lay out every thing I can think of for the owners to decide upon, and as a rule it is cut down, but the results are still good. I will illustrate several cases: An architect gave me a set of plans; asked me to lay out the entire electrical equipment. I estimated eleven thousand dollars. "No," he said, "too much. Five thousand." Finally I put in thirteen thousand dollars, and he had what he wanted.

Second case, building cost seventy-five thousand dollars. I estimated eighteen hundred for lighting. Owners tried to cut it down and finally said, "Give us what you can for five hundred dollars." This from people who could well afford to spend ten thousand dollars, and should not have failed to provide properly for lighting equipment.

Third case, a house was to cost two hundred and fifty thousand dollars. I was called in to estimate on illumination. Owners consented to a good "lay-out" costing about six thousand dollars. Upon receipt of the plans they called for me, and spent a whole day trying to economize and at midnight, with everyone worn out, they had saved about fifty dollars and were pleased with their effort toward economy. The house cost two hundred and fifty thousand dollars, and over a million altogether including grounds, etc.

Fourth case, an owner requested me to lay out the plans, before he started to build. I estimated fifteen thousand dollars, but the architect interfered to specify what I regarded as very undesirable fixtures. Finally I said to him that as I was responsible for the lighting, I was going to do it my way. I mention these few things to show what conditions the wiring contractor has to meet. Efficiency is seldom considered. Always the cost. Do as little as possible and let it go at that.

Fifth illustration, a department store owner said "Cut down your estimate two thousand dollars. I did so. After the store was finished. "Why didn't you give me better lighting?" "I did but you cut it down." "You should not have permitted me to do so. You knew what I needed and should have made me do it."

Miss Irwin: I think one point stands out in this discussion, namely, that of the attitude of the consumer, is at the very basis of the question of correct illumination in residences. Mr. Luckiesh said in starting the paper, or at least I understood him to say, that we should not consider lighting in the residence from a utilitarian point of view. While that would depend upon our definition of the word "utilitarian," it seems to me that the great thing necessary at the moment *is* to awaken public attention to the utilitarian aspect of lighting in connection

with health and efficiency. This last gentleman's remarks emphasize that point, and when owners realize the fact that an over or underlighted building is a menace not only to health but to efficiency they will become much more liberal in these matters and they will not consider too closely the initial outlay in points that are so essential. Therefore in this case the utilitarian aspect of residence lighting is the very first one to be considered.

In regard to fixture, Mr. Luckiesh said that the average fixture is simply an "object" and seems to have no purpose. I should like to ask Mr. Luckiesh what he would consider the specific purpose of a fixture to be? In my study of the function of fixture it has seemed to me that fixture is more or less designed in relation to architectural proportions and to historical periods.

This generally accounts for the lack of correspondence between the fixture and the lighting unit, and, consequently, there is a great scarcity of fixtures that have any relation to the principle of lighting. In my own humble opinion the fixture should represent the element of shadow in relation to light, thereby supplying in connection with artificial lighting an effect that we always find represented with light in nature, and one that is the basic cause of our pleasure and benefit in connection with the effect of light in nature. Now of course interior, or artificial lighting is of a different nature from the daylight effect, but if we analyze, we find that if artificial lighting is to mean anything in the home it must emulate those therapeutic and beneficial effects that we derive from light in nature. If the fixture artist would combine with the lighting artist and with the Illuminating Engineer to achieve this result, it seems to me that a great deal could be accomplished.

In regard to the semi-indirect bowl, I do not agree that it is undesirable and that the dome is more desirable. I think that in the dining room the effect that we should produce is one of hospitality and warmth and that all undue glare should be removed from the eyes of those seated at the table. The semi-indirect bowl provides such conditions more adequately than the old dome. But why can we not improve the character of the semi-indirect bowl? I think that is the point that should be dwelt on rather than the undesirability of the semi-indirect bowl. While I heartily agree with Mr. Luckiesh in his aversion to

fixed installation, still we must use what we have, and since we find such outlets provided in nearly every type of building at the present moment in connection with lighting, the best thing is surely to effect some compromise in connection with the fixture that is to be related to such an outlet and to make that fixture of as desirable a quality as possible, namely to provide the maximum light with the minimum strain upon the individual being subjected to it.

I was very much interested in the pictures shown on the screen developing the different delicate Color effects, used in residence lighting, and there is just one suggestion that I should like to offer. In my experiments with the use of Color in illumination, I have found that a very delicate lavender is more sensitive to various Color effects than the grey. I have experimented with both and I have found that lavender gives an added glow to the more delicate and brilliant Colors and a greater depth and richness to the deeper Colors used in illumination.

MR. WHITE: Mr. Luckiesh has pointed the way to the millenium when the retail electrical dealer will be able to sell light the way Duveen sells pictures. I am sure we all hope that time will come. However, I feel that if we are going to make any progress we will have to make it by practical methods, otherwise there will be no progress.

I am in sympathy with Mr. Luckiesh, as I have always felt that lighting is a far more accurate art than it is an accurate science. I mean by that, that after we have devised the various means for producing certain illumination, we can take this apparatus and we can take our measuring instruments, and with these we can design a certain installation, and we can measure the illumination and come fairly close in results to what we have designed. But the same engineer who will prescribe the methods whereby we are to do that, will make a table of the intensities of illumination required for various occupation, and in that table will be found such items as "From 5 to 15 Foot-Candles." That looks very much like throwing away the necessary benefits from the accuracy that we have taken pains to provide. However, the table of intensities is right. We can be perfectly comfortable under a very wide variation of intensi-

ties. We do not need accuracy in that respect. Therefore, I say that illumination is not so accurate a science as we sometimes try to think it is.

But if we will take the characteristics of lighting and make that the predominant thing rather than the mathematics of lighting, we will find ourselves on very much surer ground, and on ground where we can progress more rapidly from one experience to another, and find affects which are sure to be pleasing and satisfying to human needs. The engineer who merely produces a measured illumination by one of many methods cannot be equally sure that the people who live in that room are going to be pleased with the lighting.

Mr. Luckiesh has emphasized the necessity for selling lighting effects, and I am going to tell you about one thing that is being done because it is being done in a way to reach a very large proportion of the country which is served by electric lighting. Within the last few years I have been associated with Mr. Rex Cole in putting on the market a lighting fixture which consists of a simple metal ring with one light inside of it and a glass bottom. What we set out to provide was a pleasing lighting effect. We were so sincere in our planning to produce pleasing lighting effects that some people thought we did not care at all about what the thing looked like that was to produce this effect. We did care that it should be practical to distribute this thing all over the country. We tried to make it easy for everybody to have, and for all of the distributing agents to be interested in as a commercial proposition. But what we were working toward all the time was that we should be able to make something to produce a better lighting effect, and which everyone could take and dress up as he pleased, and have color effects and shades of any kind that he liked. If he wanted to charge the tint of the light, he could put a silk cover over the bottom.

Now things of this kind are teaching the dealers to sell lighting effects. To make that point clear, I should point out what Mr. Cole is doing to teach the dealer who otherwise would hang the lighting unit up in the midst of a lot of fixtures where it might as well be a mouse-trap. To make sure that the dealer presents the lighting effect properly to the public, he has had portable booths built, about eight or nine feet square, and is

selling these booths to the dealers with instructions how to use them to illustrate lighting effects. The dealer puts only one unit in the booth, trims it up, and shows the lighting effect. You can make the unit look like anything you please, but the thing that is always demonstrated is the lighting effect.

The only thing wrong with this educational effort from Mr. Luckiesh's standpoint is that this lighting unit hangs from the ceiling. This is a matter of opinion, but we have got to take the country as we find it. The ceiling outlets are there, and if we are going to sell these effects we must sell them for the lighting outlets that exist.

PROFESSOR SCOTT: I have been thinking and puzzling and talking about house illumination for a good many years and this to me is the best dissertation because it has gone into the reasons why, and has analyzed the situation and has given principles. The real trouble is that we are dealing with so many things that are connected and are so different. We can have a physiological stimulus but what we want is an artistic effect. We are told to leave the first and go clear over to the other which is psychological.

A good many of these things may seem very small. Some friends who were putting up a three thousand dollar home consulted me with regard to illumination. There was the matter of a choice between two fixtures, one for twenty-eight dollars and the other for thirty-two dollars, and the question was which was the best.

Another point is that many people in designing a house make a study of it. They take clippings of different houses and different designs of houses from various magazines and newspapers to compare. If we wish the same kind of people to know the principles that have been given in this paper in such an admirable manner, we should have one of these popular readable kind of articles giving almost verbatim the things that have been here presented and undertake to see it published in various magazines dealing with plans for house building. A writer who can describe scientific terms and artistic considerations in a readable way, could thus educate two million or more readers a good deal more quickly than we can directly through the efforts of the Illuminating Engineering Society. What are we doing now? We are

taking a subject which is most important in the illumination of the home and we have only a couple of dozen people. And of jobbers and contractors, how many ? Two. Most of the people here are illuminating people anyhow and we haven't struck the home builders at all. We must reach them in some other way.

PROF. CALDWELL: It always pleases me to hear Dr. Luckiesh talk on this subject. He describes so well the lighting of my own home, which I designed about ten years ago. The use of a dome over the dining table has, however, made the contrast with the rest of the room too strong, and I am now trying a device, which, while not new, is not commonly used in small rooms. I am placing reflectors for indirect lighting on two rather tall pieces of furniture at opposite corners of the room, to be used in addition to the dome. There will be camouflaged by copper rings which will simulate fern dishes. I believe the result will be very satisfactory.

MR. VAUGHN: I have been waiting for some member of the Educational Committee of the Society, to say something more definite and authentic about the educational work that our President has laid out for us this year, for there is already on foot a distinctly practical and effective plan to educate the public, the student and all users of light, through this Committee's work. I am going to have the temerity as Secretary of that Committee for to-day to ask any member for suggestions as to how best to educate through the medium of extension courses, or popular articles, or through the functioning of Prof. Scott's sub-committee which has the responsibility of introducing courses on illumination into colleges. The plans thus far outlined propose to effectively educate the user of illumination, either the present user, or, the future user, through the contact with the school children from primary grades to college days. The movement which Prof. Caldwell's Committee on Education was discussing to-day is very definite and I feel that we ought to let this audience and the Society generally know that there is a definite campaign now on.

I should like to take the time to discuss some of the details of Mr. Luckiesh's talk but the hour is late and I agree with him almost absolutely. I want to accentuate one factor of which he spoke and that is "mobility" of the lighting installation—being

able to take advantage of various changes in the lighting effects. With the portables and other fixtures intelligently arranged through the rooms, one can get many pleasing effects, and this is very desirable in home lighting.

Dr. Bell: You cannot educate the public with any degree of ease. Popular articles might reach them but popular articles on illumination that I have seen in the magazines are so bad that they would put everybody on the wrong track. I think some missionary literature might be put out.

Mr. Hughes: I think there is one great advantage to the portable lighting standards and that is the air of coziness which you can produce in a very large room. I have in mind a room of about 16 x 40 which was used by three people. With ceiling lights turned on, we were lost in the place. If we wanted to play cards in the corner we used a wall bracket and portable standard. One other interesting point for convenience, all of the wall switches instead of being inside the room were outside the room and on the same side of the door as the door knob. If you went into the bathroom, you turned on the light before you went in, this scheme worked out very satisfactorily.

Mr. Burton: I think one of the most important of Mr. Luckiesh's remarks, was his reference to the necessity of a proper electric wiring layout at the time of building the home.

It would greatly help in recommending by members of this Society, of the proper types of lighting fixtures, to see that the fixture and wall plug outlets were properly provided for.

I have in mind giving a short talk with illustrations, to the senior class of High School pupils, in Mt. Vernon a city of 40,000 people and where I reside. I had intended to bring their attention to the necessity of properly wiring a residence, and showing some lighting effects suitable for home uses.

During the past three years I have had occasion to give a short talk on residence lighting to one of the Women's Clubs in my City, and I have advocated first of all, the necessary outlets to be installed, stating what the requirements of good lighting practice are. Several members have followed the suggestions given, and have been pleased with their lighting equipment when installed.

It is a good policy to equip one's own apartment or residence first: adopting a satisfactory type of lighting unit for each room, and properly designed for the particular use.

In educating your own family first, you can then spread the gospel of Good Lighting most effectively among your immediate friends and neighbors. I have found this kind of propaganda very effective in educating the public in your immediate neighborhood.

There is a field along this line of endeavor, in which members of this Society can quietly and insiduously inform a part of the public as to the principles of good lighting practice for residence purposes.

MR. LUCKIESH: I believe that in a great many places in the home, the measure of illumination is the esthetic sensibility but there are other places where intensity is very important. For instance in the basement a 150-watt daylight lamp over the laundry trays is desirable from the standpoint of high intensity. I suppose we should have at least 15 to 20 foot candles there. The average kitchen lighting-intensity could be increased four or five times with noticeably good results and without adding much to cost.

Mr. Harrington mentioned wall brackets. I believe this was answered. I believe in brackets as secondary sources for decorative treatment.

With respect to education I remember when one of the finest technical schools in the country, was laying out its plan for buildings. Illumination was left to the last and there was one thousand dollars provided for wiring and lighting. That is just what we want to take care of at the right point.

In a demonstration room, we have at Nela Park we do not make it a point to invite the public. Nevertheless we have had a number of householders building houses who have come to us with their plans and you would be surprised to find how easy it is to provide for really good illumination, incidentally by adding 20 or 30 outlets and switches to a house after they are through laying out the lighting. But lighting possibilities must be demonstrated. I think magazine articles are a good thing when supplemented by illustrations but I do not think they are as effect-

ive as demonstrations. Sometimes the best results are obtained the longest way around. Instead of showing a lamp or a fixture, lighting effects should be emphasized. Our propaganda has been reaping some harvest. I believe that a room of this sort is necessary for the fixture dealer to do his part, and further to get the money that he is entitled to receive for lighting. Fixture dealers complain that there is no money in lighting. You do not hear the decorator complain. He gets paid for his ability as well as his work.

MISS IRWIN: Do you find houses as a rule over or under-lighted?

MR. LUCKIESH: I should not want to say. A great many of them are over-lighted. The point is when you want to read, you do not want a great amount of light. You want to sit down in the corner and have the light concentrated there. You do not like to attempt to concentrate in a large room which is ablaze with light.

The ideal I have in mind is 100 per cent. utilitarian. The purely narrow utilitarian idea is not usually artistic lighting. Unfortunately we teach art by going to the museum and making copies. We have been largely doing the same with lighting. A candelabra which was beautiful in the fourteenth century is now increased in brightness a hundred times and it is no longer beautiful. I do not believe that glare can ever be a by-product of an artistic lighting effect. The fixture men must be educated in that respect. As a rule these gentlemen are so tied to old art that they think their job is not done unless they have carefully copied everything.

We must have more missionary work such as magazine and newspaper articles, and demonstrations.

ADVANCE PUBLICATION
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GENERAL OFFICE
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INTERIM REPORT OF 1919-20 COMMITTEE ON AUTOMOBILE HEADLIGHTING SPECIFICATIONS, JUNE, 1920.

The report of this Committee presented before the annual convention of the Society in Chicago in October, 1919, referred to a revision of the earlier testing specifications for automobile headlights, making the requirements more rigid. These revised specifications were adopted first by the State of Connecticut and have since been adopted by Maryland, while New York State has recently withdrawn the earlier specifications and authorized the use of the revised specifications in all future tests. In response to a demand the Committee finds it desirable at this time to publish this revised specification in full.*

COMMITTEE ON AUTOMOBILE HEADLIGHTING SPECIFICATIONS.
C. H. SHARP, *Chairman.*

* For earlier work of the Committee, see TRANSACTIONS I. E. S., Vol. XIV, page 64, et seq. also page 101 and page 500, 1919.

RULES GOVERNING THE PERFORMANCE OF AUTOMOBILE HEADLIGHTS ON THE ROAD AND SPECIFICATIONS FOR LABORATORY TESTS OF HEADLIGHTING DEVICES FOR APPROVAL BY STATE AUTHORITIES.

COMMITTEE ON AUTOMOBILE HEADLIGHTING SPECIFICATIONS, ILLUMINATING ENGINEERING SOCIETY.

Revised May, 1920.

I. PERFORMANCE ON THE ROAD.

For the purpose of test the intent of the law governing the headlights of motor vehicles other than motorcycles and tractors is deemed to be complied with if so adjusted, arranged and operated as to meet the following conditions:

1. Any pair of headlamps under the conditions of use shall produce a light which, when measured on a level surface on which the vehicle stands at a distance of 200 ft. directly in front of the car and at some point between the said level surface and a point on a level with the centers of the lamps, is not less than 4800 apparent candlepower.

2. Any pair of headlamps under the conditions of use shall produce a light which, when measured at a distance of 100 ft. directly in front of the car, and at a height of 60 in. above the level surface on which the vehicle stands, does not exceed 2400 apparent candlepower, nor shall this value be exceeded at a greater height than 60 in.

3. Any pair of headlamps under the conditions of use shall produce a light which, when measured at a distance of 100 ft. ahead of the car, and 7 ft. or more to the left of the axis of the same, and at a height 60 in. or more above the level surface, on which the vehicle stands, does not exceed 800 apparent candlepower.

4. Any pair of headlamps under the conditions of use shall produce a light which, when measured on a level surface on which the vehicle stands at a distance of 100 ft.

ahead of the car and at some point between the said level surface and a point on a level with the centers of the lamps and 7 ft. to the right of the axis of the car, is not less than 1200 apparent candlepower.

II. LABORATORY TESTS OF HEADLIGHTING DEVICES.

By headlighting device is meant either the integral and complete headlamp or a device intended to modify in a suitable manner the beam of the ordinary type of headlighting equipment.

In order to determine whether any particular device is capable of conforming to these requirements so that its use may be allowed upon the highways of the state, it will be submitted to a competent and unbiased testing authority to be designated by the state authority, to be subjected to laboratory tests in accordance with the following specifications:

SAMPLES FOR TEST.

The state authority will submit to the testing authority samples of the device together with the printed instructions for its use as issued by the manufacturer of the device. These samples shall be assumed by the testing authority to be fairly representative of the device as manufactured and as marketed. The samples submitted shall include as much of the accessory equipment peculiar to the device (except batteries) as is necessary to operate the device in its normal manner. In the case of front glasses the samples shall be of 9-in. diameter when practicable.

REFLECTORS AND INCANDESCENT LAMPS.

In the case of devices to be used in connection with standard parabolic reflectors, the reflectors used in making the laboratory tests shall be of standard high grade manufacture of 1.25 in. focal length with clean and highly polished surfaces, and as nearly truly paraboloidal in form as practicable, and as approved for this purpose by the National Bureau of Standards.

The incandescent lamps used in connection with the laboratory test shall be of standard manufacture and as approved for this purpose by the National Bureau of Standards. In the case of devices involving the use of special incandescent lamps, such lamps together with any necessary accessories shall be submitted.

MARKS OF IDENTIFICATION.

Each device submitted for approval must bear a distinctive designation and the approval will cover only exact copies of this device as submitted. In the case that the design or construction of any device is changed in any way to alter its optical characteristics, a new name or type designation must be given and prominently indicated on the device, which may then be submitted for approval on the same basis as a new device. Special incandescent lamps submitted in connection with devices shall bear the manufacturer's normal, clear bulb rating.

ADJUSTMENT OF DEVICES.

The testing authority shall adjust the device in accordance with the printed instructions issued by the manufacturer and accompanying the same, and shall not recommend for certification any device not accompanied by such instructions nor any device the instructions accompanying which are inadequate for practical purposes. An exact description of the adjustment made for test shall be given in the report and designated as "Manufacturer's Adjustment."

TESTS.

The tests shall be as follows:

Test 1.—6-point test of pairs of samples.

A pair of testing reflectors, mounted similarly to the headlamps on a car, shall be set up in a dark room at a distance of not less than 60 ft. nor more than 100 ft. from a vertical white screen. If a testing distance of 100 ft. is taken, the reflectors shall be set 28 in. apart from center to center, and if a shorter testing distance is taken, the distance between reflectors shall be proportionately reduced. The axes of the lamps shall be parallel and horizontal, or tilted in a vertical plane in accordance with manufacturer's adjustment. The intensity of the combined light shall then be measured with each pair of samples in turn, with the reflectors fitted with a pair of each of the following types of incandescent lamps in turn:

(1) Vacuum type, 6-8 volts, 15 scp.

(2) Gas-filled type, 6-8 volts, 21 scp.

The lamps shall be adjusted to give their rated candlepower at rated efficiency. Measurements shall be made at the following points at the surface of the screen:

A. In the median vertical plane parallel to the lamp axes, on a level with the lamps.

B. In the same plane one degree of arc below the level of the lamps.

C. In the same plane one degree of arc above the level of the lamps.

D. Four degrees of arc to the left of this plane and one degree of arc above the level.

E. Four degrees of arc to the right of this plane and on a level with the lamps.

F. Four degrees of arc to the right of this plane and two degrees of arc below the level of the lamps.

In an acceptable device both pairs of samples shall conform to the following specifications for observed apparent candlepower:

Points A and B. At at least one of these points, or at some point between them, the apparent candlepower shall not be less than 4800.

Point C. The apparent candlepower shall not exceed 2400.

Point D. The apparent candlepower shall not exceed 800.

Points E and F. At at least one of these points, or at some point between them, the apparent candlepower shall not be less than 1200.

No device failing to conform with these specifications at all points and with any pair of samples submitted and with the test lamps specified, operated at the candlepowers which are specified, shall be recommended for certification. However, if the laboratory test shows that any device which conforms to the specifications with a 15-candlepower vacuum lamp or with a 21-candlepower gas-filled lamp would also conform with the specifications with a lamp of higher candlepower, such fact should be noted in the report and the upper limit of candlepower for the device in question, should be indicated.

NOTE.—The above testing directions are drawn specifically to cover the case of devices accessory to parabolic reflectors of 1¼-in. focal length. In the case of other classes of devices where these directions evidently cannot be applied literally, their intent must be adhered to and the testing positions and candlepower limitations shall govern in all cases.

Test 2.—Complete test of single sample.

A single sample taken as an average representative of the device as manufactured, shall be submitted to a complete test with a vacuum incandescent lamp of 15 candlepower, 6-8 volt rating. This test shall show its light distribution characteristics by actual measurements made in accordance with the best laboratory practice.

DISTRIBUTION OF SAMPLES.

One pair of the samples submitted shall be retained at the testing laboratory for the purpose of future reference and as samples of construction, and the other pair shall be returned to the state authority.

III. MOTORCYCLE HEADLIGHTING.

For motorcycles carrying only one headlamp the preceding sections are modified as follows:

SECTION I.—*Paragraph 1.*—Instead of 4800 candlepower, 2400 candlepower shall be required.

Paragraphs 2 and 3.—Unchanged.

Paragraph 4.—Instead of 1200 candlepower, 600 candlepower shall be required.

SECTION II.—Instead of two pairs of samples one pair of samples shall be submitted. Test 1 shall be made with one headlamp instead of two headlamps.

In an acceptable device each headlamp shall conform to the specified candlepower limitations except that at the point A or B 2400 candlepower instead of 4800 candlepower shall be required and at the point E or F 600 candlepower instead of 1200 candlepower shall be required.

IV. REPORTS.

The report of the tests shall be rendered in duplicate to the state authority and shall be signed or initialled not only by the expert making the test, but also by an executive officer of the institution making the test.

V. RESERVATION OF APPROVAL.

The intention of the specified limiting intensities in Test 1 is to define a beam which will give a safe road illumination for driving at moderate speeds and under normal conditions of visibility.

The state authority reserves the right to refuse approval of any device which although it conforms to the limits at the specified points, because of unduly dark or bright areas within the region covered by the specified points, or from some other cause, is liable to prove unsafe under the above conditions. Approval may also be refused to any device which requires an abnormal or an unduly complicated or difficult adjustment to conform to the limitations of the specifications, or which incorporates a design or mechanical construction such that it may reasonably be expected to prove unsatisfactory in practice.

VI. VERIFICATION TESTS.

The state authority reserves the right to submit from time to time samples of approved devices to the testing authority for a verification of their performance under Test 1 above. In case the verification test shows failure of any device to conform to the specifications, the state authority may withdraw its approval of such device.

TRANSACTIONS

OF THE

Illuminating Engineering Society

PART II -- PAPERS

VOL. XV | JULY 20, 1920 | No. 5

SYMPOSIUM—MAINTENANCE OF LIGHTING EQUIPMENT.

Probably no other phase of the lighting problem has been so neglected in recent years as that of proper maintenance. Modern equipment requires so little attention to keep it operative, that there is a tendency to neglect it almost entirely. The result is a slow depreciation, which finally renders the lighting unsatisfactory, and is then charged against the equipment or energy supply.

At the present time there is real need of ample and good illumination, therefore the written experience in connection with several classes of lighting, as presented before the Chicago Section meeting of December 18, 1919, is of especial importance.

COMMITTEE ON PAPERS.

MAINTENANCE OF INDIRECT LIGHTING EQUIPMENT.*

BY J. L. STAIR.

In my contribution to this evening's program, I will tell you of some experiences in the maintaining of indirect lighting installations, possibly bringing out a few points that might be applied to other types of installations.

If we refer to the files of the Illuminating Engineering Society we will find the results of a great number of tests and investigations that have been made; indicating that the accumulation of dirt and dust on lighting equipment has a harmful effect upon illumination results. In a recent investigation, Mr. Hibben concludes that the relation of lighting maintenance costs, including lamp renewals and cleaning, to the total cost of operating an office building, are in about these proportions:

Lamp renewals—.95 of 1 per cent.
Cleaning of fixtures—about 4 per cent.

Tests made at the Chicago plant of Armour & Co., show that the deterioration due to dirt and dust settling upon the lighting equipment amounts to about 10 per cent. a month. In the publications of the National Lamp Works, data and curves contribute to our fund of information on loss due to improper maintenance.

I have often been impressed with the fact that, although such information is very valuable, it has been more or less buried in the files of this Society and other societies of a similar nature.

Our problem as illuminating engineers is to get this valuable information into the hands of those who are vitally interested, such as the manager of an office building, or the operator of a plant. The average consumer probably realizes that the accumulation of dirt on the lighting equipment cuts down illumination to a certain extent. He is much more impressed when exact fig-

*Paper presented before Chicago section of the Illuminating Engineering Society, December 18, 1919.

ures can be given him, or a demonstration made in his own office to show the seriousness of the loss.

NATIONAL CAMPAIGN FOR MAINTENANCE.

In order to bring before the user of light some of the above facts, the company with which I am associated have promoted a national campaign for cleaning. The manner in which this campaign was conducted and also the manner in which a more specialized local campaign in Chicago was conducted, will be described more or less in detail.

Among the factors which tend to cause deterioration of an indirect lighting system, and hence vitally affect the illumination received, are the following:

1. Renewal of lamps has been neglected.
2. Cleaning of fixtures has not been taken care of.
3. The color of the ceiling is not proper, or it has been allowed to darken, or has not been kept clean.
4. The position of the lamps in the reflectors is wrong.
5. The suspension of the fixtures is not correct for proper lighting results.
6. The results from the reflector equipment have been ruined by the use of the wrong lamps.

The national campaign for lighting fixture maintenance was inaugurated in an endeavor to bring some of the facts enumerated above before the user of light in such a way as to get him, if possible, to do cleaning in a systematic way and establish a maintenance schedule which could be carried out at stated times.

The first step in the campaign was the preparation of a careful record, on card index, of all the installations for which information could be readily obtained. The records were kept geographically and also listed by the character of the installation, that is: Office Building, Church, Theatre, Club, Bank, Factory or what not. In addition to the general list kept at the main office, each branch or sales office also kept a list so that they would be in close touch at all times with the installations.

Circular letters were sent out to all the names listed, and usually along with this letter, which pointed out the value of proper

maintenance and cleaning, was an enclosure. The enclosure in the initial letter to the light user was a return card, which, if properly filled out and mailed to us, signified his interest and willingness to be reminded from time to time, that his fixtures should be cleaned. This card was made about the same size as the ordinary index card, so that it could be filed with the original index card. Later, the information on these returned cards could be used in compiling data in regard to maintenance.

At intervals of about sixty days, additional letters would be sent out, usually with enclosures of different kinds. Figs. 1 and 2 illustrate these, the first being in the form of a blotter, and the second a gummed label.

Although the results of the national campaign for maintenance were most gratifying, it was decided to try out an entirely new idea in an intensified local campaign, confining out efforts to the city of Chicago.

LOCAL MAINTENANCE CAMPAIGN.

The fundamental idea in the Chicago campaign was to secure the interest and co-operation of those who could profit financially through a maintenance program. In selling this idea, we received the most enthusiastic support from people who are in the cleaning business, such as window cleaning companies, etc.

Chicago was picked for the maintenance campaign because it is a typical American city. Conditions, as far as dust and dirt are concerned, recommended this city as a sort of feeling-out ground for the application of the idea. It is hoped that the application will be extended later to all the principal cities in the country.

In Chicago, a file was carefully prepared the same as for the national campaign, covering all types of indirect lighting installations. Then, following the plan of the other campaign, letters were addressed to the owners and managers of the plants and offices, with a return card attached. The style of the card to be returned by the owner is shown in Fig. 3. Many of these cards were returned to us and with the information received an effective campaign for maintenance was put into force.

DO YOUR LIGHTS SMILE?

To continue at original efficiency, your lighting fixtures should be cleaned every three weeks.

Tests on direct, semi-direct and indirect systems show a loss of ten per cent in light for every month cleaning is neglected.

Use Mazda "C" lamps- date them when put in- don't burn them more than 1000 hours- when new ones burn dim get lamps of lower voltage- don't use discolored lamps.

Clean X-Ray silvered glass reflectors easily by wiping just the inside with a soft cloth slightly dampened. (Alcohol is best). Wipe off the lamp, too.

Keep a record of periodical cleaning and re-lamping.

PASTE UP IN A PROMINENT PLACE

SERVICE DEPARTMENT
IMPORTANT

MAINTENANCE

Note date of cleaning and new lamps here.

To maintain your lighting system at the initial satisfactory condition some one person should have it in charge and attend to

(*a*) *Periodical cleaning.*
(*b*) *Renewal of lamps.*
(*c*) *Redecoration of ceiling and side walls.*

Exhaustive tests on Direct, Semi-direct and Indirect Lighting equipment show an equally approximate decrease in efficiency of 10 per cent. per month.

Where possible this maintenance should be in the Electrician's Department rather than under janitor service.

IN CHARGE ....

SIGNATURE ....

Fig. 2.

PLEASE INSPECT OUR X-RAY LIGHTING SYSTEM INSTALLED BY YOUR COMPANY.

THERE IS TO BE NO CHARGE OR OBLIGATION FOR THIS SERVICE.

NAME..............................

ADDRESS..............................

Fig. 3.

In the meantime a window cleaning company was interviewed and apprised of the enormous field that exists in any large city for the cleaning of lighting fixtures, a field never before touched. This company had practically solved the question of the cleaning of windows and there was no reason why a very profitable business could not be developed in this new line of endeavor. Prac-

tically the same kind of help could be used as for window cleaning and as the men became educated in lighting matters, some very effective work could be done.

Our first experience in making arrangements with a cleaning company were not very satisfactory, although we selected a man as a specialist in this kind of work and practically set him up in business. We printed his letterheads, cards, billheads and also a quantity of circular letters. We named the new company "The Best Window Cleaning Company," on whose letterhead in red type were these words "Lighting Fixture Cleaning a Specialty. We are responsible for breakage."

The first idea was to keep the fixture maintenance work allied with that of the window cleaning company. After some experience, however, it was found unnecessary and even undesirable, to tie the two together.

A change in the scheme was made, and a second company, larger and more responsible, was approached. We succeeded in getting this company to add a new department to their business and call it "The Lighting Fixture Service Company." We printed business cards for that company also, reading—"Lighting Fixture Service Co. Lighting System Maintained. We are responsible for breakage." The responsibility clause printed on the card was an added feature which we thought would act more or less as a drawing card to help create the interest of the manager of the office or plant.

Our co-operation with the new company has been very successful. We have had no difficulty in introducing the maintenance scheme in a great many offices and other classes of installations. We have to-day active maintenance work in operation through this Lighting Fixture Service Company, which is entirely independent of us. We furnish "leads" and assist the company in getting business.

One of the pleas that is made to the owner of the building or the superintendent or manager is that the problem of maintenance of the lighting system is entirely taken out of his hands, just as the maintenance of his auto is taken out of his hands in the garage or service station, or as his towel or ice water service is taken out of his hands and cared for.

The fixtures are cleaned at stated intervals, preferably once a month, and contracts are made on that basis. In addition to the cleaning of the equipment, lamps may be renewed. Many of the customers like that part of the agreement, and desire that the maintenance man supply new lamps when the old ones are burned out, the cost of the lamps being taken care of in the contract.

The cost for maintenance, or the fees charged by this Lighting Fixture Service Company for cleaning fixtures, are of interest. The cost varies according to the style of the fixtures and the number of reflectors and units in the installation, as well as the accessibility of the lighting equipment. Some fixtures have but one reflector with a single large lamp. Others have possibly four to a half dozen reflectors, each with its individual lamp. In that case the cost of cleaning the fixture is more than for a single lamp fixture. These and other factors influence the cost of cleaning.

The average cost for cleaning a variety of types of installations is found to be about 21 cents per fixture per month. This includes cleaning only once a month. Costs for various types of installations vary from 13 to 38 cents for one cleaning, per fixture. This fee includes any breakage that might occur to the lamp or to the reflecting equipment during the cleaning operation.

In carrying on the campaign, various little "stunts" were resorted to. One of these was a simple means of showing the owner that his fixture was dusty or dirty. A small mirror about 6 inches in diameter was mounted on the end of a collapsible stick, something on the order of a fishpole or a tripod for a camera. By properly placing this mirror above the fixture, the accumulation of dust or dirt inside the fixture could be easily seen without resorting to the use of a ladder or chair, or without lowering the fixture. A foot candle meter was frequently used to show the increase in light intensity due to cleaning of the fixture or renewal of the lamp. In some cases, by merely putting a new lamp in the socket, effective illumination was trebled.

Various forms of cleaners were employed. Some were made of lambs' wool, which were very easy to use. By means of these cleaners the maintenance man could clean the fixture without removing the lamp or reflector equipment.

The man who took actual charge of the maintenance operations was given a short course of training with reference to lighting

and especially with regard to lamps and various styles of reflecting equipment. Hence, when the man went out on a job he was prepared not only to clean the fixtures, but also to give suggestions as to decorations, proper kinds of lamp for renewals, with respect to size and voltage, position of the lamp in the reflector, the suspension of the fixtures, and many other factors that influence the proper performance of the system.

MAINTENANCE DEPARTMENT

Date.............. Inspected by................

I have to-day inspected the indirect lighting at

NAME OF FIRM ....

ADDRESS ....

PERSON INTERVIEWED ....

CLASS OF INSTALLATION ....

Description of its condition is indicated below.

1. CLEANED BY.............................. How often..............
2. CEILING—good—fair—poor—color................ will retint..........
3. SIDE WALLS—good—fair—poor—color............ will retint..........
4. SUSPENSION—too short—too long—O. K..........................
5. LAMPS—"C"—"B"—tip up—tip down—too large—too small—dim—burned out—position O. K.—clean—dirty—auxiliary O. K.........
   ....
6. REFLECTORS — modern — old — clean — dirty — broken—missing—out of holders ....
   ....
7. DIFFUSER—clean—dirty—broken—missing ....
   ....
8. FIXTURE BOWL—clean—dirty—broken ....
9. SHADEHOLDERS — correct — too short — too long — reflector hanging on lamp ....

Recommendations and Remarks on reverse side.

FIG. 4.

Some of the printed forms used in the campaign are shown in the illustrations. The form shown in Fig. 4 was filled out by the inspector upon first visiting the installation. Many installa-

tions were inspected by our own men in order to get things started. The information secured by this inspection, when recorded on this form, gave a fairly complete record of the conditions of the installation.

In addition to the efforts that we put forth on this campaign, the cleaning company also sent out form letters and was active in securing new business. The results of the campaign have been very gratifying and indicate what can be done in extending this service to all the cities in the country. It not only has been a means of rendering a service to the customer, but it has also saved a few installations which were just about to be condemned on account of the accumulation of dust and dirt or because lamps had been burned beyond their rated life. It was also found that after bringing an installation up to date for a customer, many times repeat business was obtained that more than paid for the expense of the campaign.

DISCUSSION.

MEMBER: What means did the cleaning company use for determining when a lamp should be renewed? I assume they don't allow all the lamps to burn out. Often we have tried to urge customers to put in new lamps when the lamps blackened to a very great extent, and we found they were, in many cases, desirous of letting the lamp go until it burned out.

MR. STAIR: Up to the present time no data or records have been kept of lamps that have been renewed, but it is a part of the plan to have the maintenance man eventually keep a careful record of all lamp replacements. Large companies, like Sears, Roebuck & Co., for instance, have a system for keeping record of every lamp that is used in their establishment. Data is kept regarding the size of each lamp and the date of its renewal. A system of this nature is to be incorporated into the maintenance campaign work, but has not yet been put into effect.

This plan or campaign has been explained to companies which are large users of lamps and we have prevailed upon several of them to establish a regular maintenance system. The larger companies are not so much interested in the cleaning by an outside party, as they usually have a well-organized janitor and electrical service and take care of their own renewals.

MR. CRAVATH: How far along has the maintenance matter gotten in Chicago. Is there only one company doing that kind of work or approximately how extensive is it?

MR. STAIR: The campaign has been operating in Chicago about nine months. The work has been confined to one cleaning company so far. Closer co-operation has been obtained and better results secured than by putting the work into the hands of two or more companies. Since the one company has understood that this proposition is exclusive with them, they have exerted a greater effort than they would have otherwise. There is work enough of this nature in a city like Chicago to keep several cleaning companies busy, but in order to get the campaign really established, we have been working only with the one concern. Extending of the campaign to other cities has not yet been taken up, but we expect to do so very soon.

MEMBER: I would like to ask Mr. Stair if the figures quoted are the prices that are charged for the work or are they the actual cost?

MR. STAIR: The figures quoted for the cost of cleaning are taken from the estimates or the contract prices of the cleaning company. They are not based on any particular cost records.

MR. STAIR: For textile mill lighting we have frequently installed glass covers over fixtures where a great deal of lint was found to be flying in the air. In some instances the amount of lint is so great as to fill up the indirect lighting bowl in one day, probably amounting to as much as a market basket full. Future developments will no doubt provide for these severe requirements and bring out equipment that will be practically dust and dirt proof and yet give most effective lighting results.

MR. CURTIS: I might say that the trouble that has been experienced mostly is with the fixtures that have a glass bowl of the luminous type. We have obviated the difficulty that arose there. The inside of the bowl is usually of a rough finish, collects the dirt and dust and is difficult to clean out. We have a glass bowl,

which, without the reflector, would be the regular semi-indirect type of fixture; but the luminous bowl fixture includes a reflector within the glass bowl, which has in the bottom a diffuser, the purpose of which is not to keep the dirt out from the bowl, but to illuminate the bowl. The light obtained on the working plane is the light reflected from the ceiling. Usually in the typical fixture there is a space between the reflector and the outside of the bowl all the way round, which allows the dirt to get down into the bowl. The reflector would probably include about that proportion of it (indicating on blackboard); looking down on the fixture, this would be the open part: we have set in here a piece of tin with the edges turned in, which exactly fits in the space.

SERVICE ON RENTAL FIXTURES BY COMMONWEALTH EDISON COMPANY.*

BY MR. F. A. KAUP.

In 1907 the Commonwealth Edison Company decided to furnish the newly developed, highly efficient incandescent lamp in rental fixtures to take the place of arc lamps which were being supplied at that time. The matter of up-keep was given careful consideration, and when contracts were taken, they carried a provision that the Company would keep up the maintenance at a small monthly charge which was made to cover the expense of this work. That this idea was a sound one was proved within the first few years, for it was found that customers would neglect their lighting equipment with a consequent loss in efficiency, and would abuse their lighting equipment to such an extent that it would be practically useless.

The rental fixture proposition of the Commonwealth Edison Company proved to be a very popular one, and in the twelve years that this form of lighting has been in vogue, we now have under live contracts 24,271 store fixtures, 679 exterior lighting brackets, 16,084 factory fixtures, 2,300 street posts and 6,800 subway lamps. In addition to the above, the maintenance department looks after 3,100 rental signs and 957 arc lamps, more than half of which are used for City street lighting. The total connected load in rental equipment is 6,981,000 watts.

The rental equipment is furnished free to the customer which includes wiring and fixtures. The work of the maintenance department consists of keeping this equipment in as good order at all times as nearly as possible as when newly installed. This includes periodical cleaning, necessary repairs and renewals of lamps, fixtures and fixture parts, replacement of defective wiring, all without extra charge to the customer. In the case of rental equipment, the usual service charge of 35¢ made by the Company is not charged customers when repairs to rental fixtures are necessary.

*Paper presented before Chicago Section of the Illuminating Engineering Society, evening of December 18, 1919.

The organization necessary to carry on the work of maintenance consists of a supervisor, 3 district foremen, 3 field foremen, 5 work dispatchers, 41 repairmen, 29 patrolmen, 45 fixture cleaners, 31 sign cleaners, 26 switch-boys and 7 clerks and stenographers. The City is divided into 3 districts, each in charge of a district foreman. Supervising the outside men at work, checking up the kind of work performed and inspecting the customers' equipment periodically is taken care of by a field foreman in each district. Twenty-one vehicles, mostly electric, each carrying 2 repairmen, keep in touch with the office hourly—repair work including lamp renewals being taken care of very promptly. Owing to the fact that rental fixtures are equipped with lock sockets makes it necessary in most cases that lamp renewals be made exceedingly prompt. Repair and lamp renewal service is usually given a customer anywhere in the City within one hour be it day or night, Sundays or holidays. Repair work and lamp renewals at night are made by patrolmen whose principal duties are turning on and off of flat rate signs, street posts and exterior brackets.

A repairman is likely to be called upon to perform one of many duties and his vehicle is equipped to take care of almost any possible emergency. His principal duties are hanging and removing fixtures, setting and removing meters, making wiring and fixture repairs and renewing burned out lamps.

The duties of a patrolman are to turn on and off flat rate business, make necessary repairs at night and report burned out lamps which are renewed the next day by repairmen.

The duties of fixture cleaners are to clean fixtures in customers' premises periodically, renew burned out lamps and make minor repairs to sockets, etc.

The field foreman in each district arranges the work in route order, and each day's work is made out in advance by a clerk in the office and the customer's signature obtained at each visit. This is recorded by the same clerk, making an absolute check on the reports of each man. With the immediate supervision given by the field foreman to each maintenance man, it has become practically impossible for a maintenance man to shirk his duty without being immediately discovered.

Rarely do any of our 25,000 customers using rental equipment complain that the work for which they are paying is not being satisfactorily performed. Being equipped to make repairs and lamp renewals on rental fixtures very promptly the maintenance department can execute on 24 hours notice new fixture hanging jobs in premises already wired, and whether it is a rental fixture or a fixture purchased by the customer, we have thus far been able to give our customers immediate service in hanging these fixtures. It has been the policy of this department to co-operate closely with other departments and complaints and criticisms are invited and gratefully received.

Besides maintaining fixtures, this department looks after rental signs and lamps located in the subways at railroad street intersections. Forty men are engaged in sign maintenance work and 26 high school boys are used to turn the lights on and off in railroad subways, which work does not interfere with school duties or hours.

DISCUSSION.

Mr. Tillson: Mr. Kaup has shown us pictures of some of the heart-breaking things that happen to our customers' equipment after it has been installed. Suppose that a solicitor takes a prospect for new equipment to look at a job installed by him some months before and finds that the most ignorant man in the shop has raised the reflector or has inserted a lamp of the wrong size, or has removed an eye shield, or has in some other way destroyed the value of the equipment. The solicitor loses the installation of the new equipment; the lighting company loses its revenue from current; the fixture manufacturer loses his sale of fixtures; perhaps the illuminating engineer loses his reputation; so that this situation is likely to be very serious and anything remedial that can be done, as Mr. Stair's company is doing, is a great thing. I question whether we can make a plant owner clean his own fixtures so that any step to make a fixture self-cleaning, or very easily cleaned, is a desirable thing.

I don't know whether we can congratulate ourselves on the fact that although we have 50,000 fixtures on maintenance there are few complaints. Often the owner will not complain until his fixtures become dilapidated and disreputable wrecks.

A fixture has been devised primarily for installation in foundries that is self-cleaning. The lamp cannot be lighted without cleaning the reflector. When the cord is pulled, a rocker arm pulls the wiper blade against the glassware and sweeps the dirt before it, and as the tension on the cord is relieved the wiper blade falls away from the glass so that the dirt is not re-deposited on the return stroke. Unfortunately this device does not renew the lamp. In my opinion this method of attacking the problem will be used a great deal in the future not only in this particular type of fixture but for semi-indirect fixtures of all kinds.

MR. ARENBERG: How are the pull cords arranged ?

MR. TILLSON: We run a steel cable to the nearest post, or down the wall. The fixture must be guyed in the opposite direction, but we have found no difficulty whatsoever in doing that. I don't believe that is a very great difficulty. The guy, or anchor, is just ordinary No. 14 galvanized wire. There is no great pull on it. Any light wire is sufficient to counteract the pull you give to clean the fixtures.

MR. ARENBERG: If you have four fixtures in a row, across the room, and you were to run your cables as described the cables would come directly under the other fixtures. The cable on the far fixture would come directly under the one this way of it. I was wondering how you kept them for interfering with each other.

MR. TILLSON: The scheme is to run the pulling cords diagonally, rather than across the room or even lengthwise. That is, where necessary. Every factory is divided into "bays." These bays are usually defined by pillars or posts—so that if there were both self-cleaning fixtures and ordinary fixtures in use, it wouldn't be necessary to run the pulling cables, underneath the ordinary units to the wall for operating them; the natural thing to do is to bring the cables over to posts and thus avoid interference with any other fixture in the room. The self-cleaning fixtures would then be guyed to opposite posts.

306

Difficult maintenance; bracket swings into building cleaned from a window

Duties of a maintenance man varied, street lamp without lowering device.

306²

Hazardous sign maintenance; absolute reliance is placed on security of guy lines.

Example of varied work maintenance man, ornamental street post.

306³

Fixture maintenance man entering store. Case contains lamps, repair parts and cleaning cloths, etc. He carries his own ladder to every customer.

Example of abused fixture. Socket replaced by two drop cords.

306 4

Shades on fixtures, raised by customer eight inches.

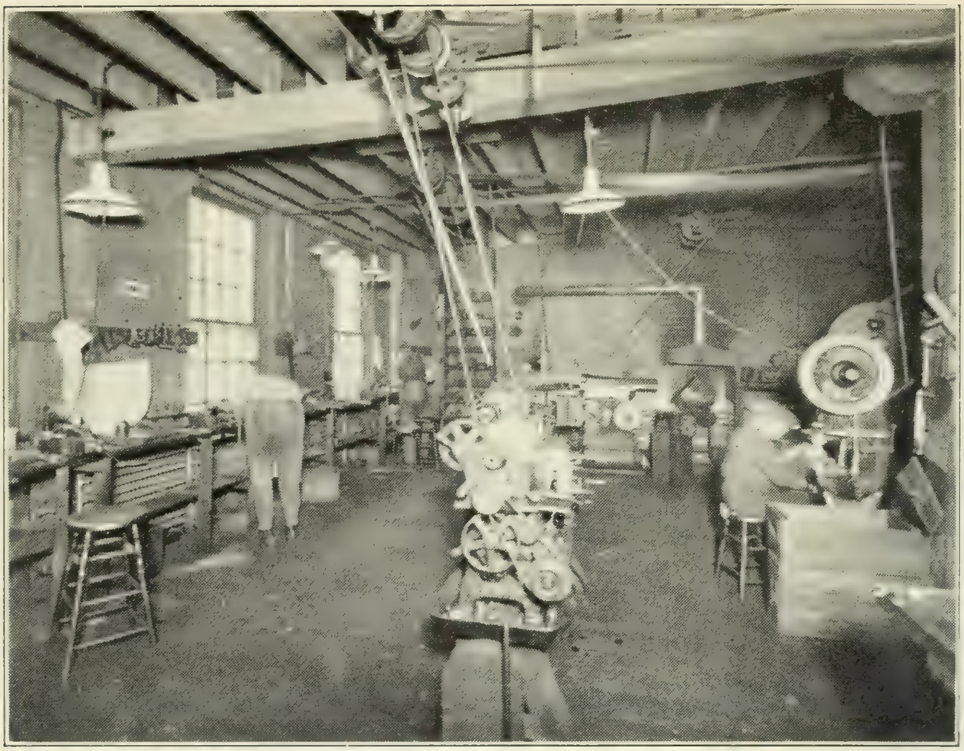
Example difficult maintenance; high position of fixtures floor covered with debris

Example of abused fixture, drop cord fifty feet long used to operate motor in rear room.

Example of abused fixtures socket removed. Benjamin plug substituted, 200 watt clear type "C" lamp suspended 24" below fixture and several motors operated from remaining sockets in Benjamin plug.

Example of neglected and dirty fixtures. Not being maintained under contract.

Example of difficult maintenance. High fixtures, one of them placed directly above tank containing molten zinc [illegible]



Example of abused installation rental fixtures, Benjamin 3 way plug in socket from which are three extensions.

Example of difficult maintenance, high position of fixtures in foundry floor covered with debris and heavy castings, etc.

CHAIRMAN: You advocate this fixture particularly for places where the dirt collecting conditions are very severe. You wouldn't recommend fixtures of this type for any installation where some attention has to be paid to the appearance would you ?

MR. TILLSON: I think that the application would naturally be foundries, roundhouses, boiler houses, cement and flour mills, and places of that nature, where high mounting of fixtures as a rule, make them inaccessible, and appearance is not a great factor. I expect to see the principle of this fixture grow to include other interiors and other styles of fixtures, but, as the chairman has said, those are probably the worst interiors we have to deal with now. For example, Mr. Kaup spoke of one installation that was inaccessible after nine o'clock in the morning, because in cleaning a fixture dirt would be dropped down into the molds, causing damage. This self-cleaning unit of course, would not drop down enough dirt to cause any harm.

Referring again to the details of this fixture development work is now being carried on, looking to the elimination of both the glass cover plate and the guy wire. Present indications are that both ideas are thoroughly practical.

MAINTENANCE OF STREET LIGHTING.*

BY MR. HENRY NIXON.
Deputy Commissioner of Electricity, City of Chicago.

MR. NIXON: In responding to the request to talk on the City of Chicago's methods of street lighting maintenance, I will confine myself to facts rather than to theories involved. While we have made some photometric tests of street lamps under various conditions of weather and fixture cleanliness, these tests have been very meager and we found that the results never indicated to us the number of times a lamp should be cleaned per year and hence, we have to a large extent followed the "rule of thumb" method in the various districts of the City such as the residential, commercial, factory districts, etc.

The street lighting system of the City of Chicago consists of approximately 50,000 lamps, of which 24,000 are of 100 candle-power incandescent type and 25,500 are of 600 candle-power incandescent type, all owned and operated by the City. In addition, there are about 9,000 gas and gasoline lamps of approximately 50 candle-power which are rented from a contracting concern.

The difficulties confronting the Bureau of Operation, due to faults which are notoriously inherent in all municipally owned and operated systems, are more marked than in any other bureau of our department, I believe. In addition to the difficulty of limited finances, the labor problem in this branch of the service is exceedingly serious; for example, the patrolling, renewing and cleaning of our lamps, globes and fixtures, is controlled very largely by the agreements which we are able to make with the union performing this class of labor. In this connection, the conditions with which we are confronted, are exactly opposite to those described by Mr. Stair, under which cleaning of interior fixtures could be done by the same class of labor as window cleaning. The union with which we deal, requires such work to be done by an electrical man, belonging to the same union as the maintenance men which, of course, greatly increases our costs.

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Our patrolling is governed by the types of lamps, due to the fact that the various types are spaced differently on the street. The 600 candle-power lamps, which are mounted at a height of 20 feet on the average, and spaced about 220 feet apart are patrolled by a man in a machine assigned to 1,100 of this type of lamp. His duties are to look at every lamp every night, replacing at night any burned out lamps in fixtures equipped with lowering apparatus. On fixtures which do not lower, the burned out lamps are replaced the next day. The same method is used in the case of a broken globe. In a few districts which cannot be laid out efficiently to be patrolled by a man in a machine, a man on foot is assigned 550 lamps. His duties are the same as those previously outlined, except that he does not attempt to replace any broken globes at night. Under both of the arrangements mentioned above, it is necessary to send a lamp changing wagon to replace broken globes or burned out compensators on all fixtures not equipped with lowering apparatus. This is made necessary because of the unhandy working conditions and the danger involved, where one man attempts to do such work alone. Our 100 candle-power incandescent units are mounted tip up on a standard approximately 10 feet 6 inches to the center of the light source, and are patrolled by a man in a machine, covering 1,500 lamps every night. He replaces all burned out lamps and broken globes at the time same are noted.

Of a cash cost for the 100 candle-power unit of $9.30 per year, $2.84 is for patrolling, renewing and cleaning of which $1.80 is for the first two items. The cleaning is, by virtue of the City's financial stringency, largely a matter of whatever is left over from the patrolling and renewing; in this case $1.04. Of a cash cost of $25.50, approximately, for the 600 candle-power unit, $5.70 is our cost for the patrolling, renewing and cleaning, of which $3.60 is for patrolling and renewing, leaving $2.10 for cleaning. We have tried several ways of improving our cleaning method but it all works back to the proposition that we are required to use a particular class of labor, which is quite expensive, and we have therefore never been able to cut those costs very materially.

Our present method of cleaning is to assign a man to a district, for which he is responsible, and in which district he has to clean

50 lamps per day, probably a fair allotment considering the variagated system which we operate. Some lamps lower, others do not, some are mounted at a height of 22 feet and some as low as 16 to 18 feet. This means the man must carry a long ladder, or he must have several ladders at different locations where they can be readily procured. Under this arrangement, cleaning 50 lamps per day, his district can therefore be so laid out that he will cover each lamp every three weeks in business districts, while in residence districts, we do not attempt to clean oftener than once every six weeks. We have tried, using a gang system, as we call it, under which a foreman with a gang of 9 or 10 men with an automobile to carry ladders, soap powder, etc., take care of large districts of the City and we have found this to be a very good method, and I believe this is the system which we will eventually use. We have tried it out for only one month, and therefore have no comparative costs, but it is certainly a better method than the individual method, giving better results in cleaning at probably a smaller cost. We find soap powders, or cleansers are better than any wet method of cleaning the globes, because at some seasons of the year the wet method is practically impossible.

A short time ago we made some time studies covering the cleaning of lamps, and while they were not all that might be wished, I believe they give us a very fair average on this activity. They showed us that a man working on a schedule of 50 lamps per day, cleans a lamp in from 7 to 9 minutes, an average of 8½ minutes per lamp; the record of 7 minutes was made on a lamp equipped with lowering apparatus and those requiring 9 minutes, were on poles which it was necessary to climb. This difference in cleaning time was not so great as most of us would have expected. The cleaner was aware that we were timing him. Whether the figures would hold good in cases in which the cleaner did not know that he was being timed, I cannot say, but at least I would expect the same variation to hold between the time of cleaning fixed lamps and the time required to clean those equipped with lowering apparatus. Due to the fact that our system is operated with a grounded neutral, it is very hard on lowering apparatus and, from the above figures, we have decided that it does not pay us to maintain lowering apparatus at considerable expense to obtain this small saving in cleaning time.

We are anxious to minimize the amount of cleaning and in that direction we have made some investigations which might be of interest. The most important problem seems to be that of keeping the dust out of the inside of the globe. The outside dirt never troubles so much, but especially under elevated railroads and along steam railroads and in the dirtier business and factory districts, the dust accumulates in the globe much more rapidly than on the exterior. In this connection, we have experimented in what we call a dustproof fixture. To be dustproof, the fixture must of course be non-ventilating, and the first step was to determine whether or not such a fixture would shorten the life of the lamp enough to offset the gain in the smaller cleaning costs which we were attempting to make. In the test which we conducted, (not a very extensive one but one which we believe proved our point) we learned that the temperature of the fixtures which we were using—a ventilating fixture with a 600 candle-power unit—would only increase from 6 to 30 degrees, when the ventilating feature was eliminated. A copper jacketed fixture, with the ventilating ducts closed and the heat dissipated by radiation only increased 34 degrees to a maximum temperature of about 369 degrees Fahr. and in a cast iron fixture, normally operated with ventilating ducts, it was found that the temperature only increased 6 degrees when these ducts were closed; the temperature rising to a maximum of 364 degrees Fahr. These tests were made in an enclosure with an ambient temperature of 100 degrees, which appeared to be about the worst condition with which we would ever be confronted. As a result of these tests, we have designed an entirely enclosed cast iron fixture with a felt gasket for the outer globe to seat against. The small number of these fixtures which we have purchased for trial, have only been in service about two or three months, so that I am unable to give you any figures to show that this type of fixture will be successful, but inasmuch as it will undoubtedly keep the dust from accumulating inside the globe, it will reduce the cleaning cost to a minimum, and certainly the small rise in temperature, which we found to result, cannot be very detrimental to the life of the lamp.

As to the method of reporting lamps and keeping records of their life, the City does not maintain a very complete system. The patrolman reports by telephone each night to the load dis-

patcher's office. We are now installing our own automatic telephone board with street boxes at convenient locations and an early report is particularly desirable where it is necessary to replace compensators or globes at fixed locations, so that the material can be made ready for the replacing crew before 8 o'clock in the morning.

At one time we kept what we called data lamps, or test lamps, at stated test locations. An accurate record showing the date of installation and date of failure was kept, and the resulting life at these test locations was used on a percentage basis to govern the replacements made by the manufacturer to recompense the City for defective lamps. Because of the fact, however, that the City is getting more hours out of every type of lamp than the guarantee called for when in effect, we have discontinued that exact method of checking our replacements and are now simply keeping track of the number sent out to the patrolmen. From the number of lamps in service we can, of course, easily determine the average number of hours per lamp. As the lamps arrive in the store room from the manufacturer, they are tested and defective ones are immediately returned to the manufacturer for replacement. Those lamps which go out to the patrolmen and burn less than one night, are also classified as immediate burn-outs and are returned to the manufacturer for replacement. Our results show that we are getting approximately 2,200 hours out of the average lamp, and from one type of lamp which we are using, we get 3,000 hours. This is a special lamp designed by our department. It is intended to give 9,000 lumens at 10.7 amperes, but it is operated on our circuits at 10 amperes and gives approximately 6,000 lumens under such operation. We would expect to get something like 7,000 hours from a lamp so operated, but we have never obtained more than an average of about 3,000 hours, indicating that the item of breakage is far greater than we had any idea. Some of this breakage is, of course, malicious. In some parts of the City we have five and six, and even more replacements per year, due to boys using the lamps for a target. In some parts of the City we have even had to dispense altogether with the diffusing globe and put on a heavy steel screen in order to protect the lamp. Another cause of shortening the life of lamps considerably, is the breaking of the filament by careless

handling of lowering apparatus. We have had considerable difficulty with this, often finding as many as 20 or 30 lamps out on a single circuit on the night after a careless cleaner has been over that circuit.

DISCUSSION.

MR. NIXON: One development we thought of trying was using a tower wagon, but we encountered difficulties with trolley wires, and we have never been able to obviate these difficulties.

CHAIRMAN: I believe that tower wagons are in use in Philadelphia. They are electrically operated trucks with platforms that can be raised and lowered. These trucks can be controlled from the upwardly extended platform as readily as from the seat. Not long ago I read of a scheme being used in Indianapolis that is quite different from the one Mr. Nixon mentioned. He said the city attempted to use wet cleaning and it was not found practical. The scheme used in Indianapolis I believe is to use a special type of cleaning wagon with cans containing hot water. These wagons return to the power house three or more times a day to get a fresh supply of hot water. By this method it is claimed they can keep up their cleaning even during cold weather. They seem to have found there that it was highly desirable to clean with water and soap. That is, however, perhaps a matter of personal opinion. I doubt whether that has been the general observation in most cities.

MAINTENANCE OF ELECTRIC LIGHTING EQUIPMENT ON THE LINCOLN PARK SYSTEM.*

BY C. H. SHEPHERD.

Electrical Engineer in Charge.

The Commissioners of Lincoln Park control and operate a system comprising Lincoln Park, five smaller parks and about 22 miles of boulevards. A total of some eight to ten thousand electrical outlets, varying with the season of the year, is required to give the necessary lighting service.

Our electric lighting maintenance proposition naturally resolves itself into the maintenance of inside and outside lighting equipment, the two branches being entirely distinct from each other. The inside lighting maintenance is taken care of by men rated as maintenance electricians, who not only renew lamps, but clean, replace and maintain all inside lamps, reflectors, sockets, wiring, switchboards and the like. We find that these men receive special calls to come to each building on an average of once a week throughout the year. The instructions given to the various men in charge of the different buildings are that in case of any kind of electrical trouble, the system operator shall be immediately notified, a man, or men being sent as soon as possible to restore normal service. Other cases of breakage, outage, dirty equipment, etc., are taken care of on the regular scheduled visits of the maintenance electricians. At some special locations we leave a stock of lamps, the local men being allowed to replace lamps or clean reflectors in cases where the electricians are not available when needed, or where it would be too difficult to get them into the particular place where the equipment is installed, such places, for instance as the Zoo. We do not attempt to give regular service in all portions of the Zoo but in some places a stock of lamps is left for each building and replaced by the keepers when necessary. We have found that the electricians do not care to go into a cage where there are lions or animals of a similar nature. The keepers renew the lamps and clean them.

The problem of interior maintenance is, of course, the simplest part of the work. The total number of outlets inside, varies

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from some six to eight thousand in service at any one time, depending on the season, the maintenance of these having few special features.

The exterior system is an altogether different proposition. On this part of the system there are about 1,700 series lamps and 300 multiple lamps for the outside boulevard and park lighting, varying from the 15 ampere, 400 candle-power, tip up burning type C lamp up to the 1,000 candle-power, 115 volt multiple type C lamp. Our standard system of boulevard and park lighting consists of a 15 foot concrete post on which is installed a 15 ampere, 400 candle-power type C lamp, enclosed in a 20 inch globe. The lighting for bathing beaches, etc., is accomplished in some cases by pendant lamps but in most cases by flood lighting. We follow a regular schedule in the maintenance of boulevard and park lighting, the work being done by the crew assigned to this territory, while in the small parks the maintenance is taken care of by men who are assigned to small park duty altogether and to no other place.

In the exterior lighting system controlled from our main substation, we have 16 series circuits. At one time we had a larger number of circuits in operation, but in changing over from arc lamps to type C lamps we were able to reduce the number of circuits very materially. For instance we had as standard equipment an A. C. enclosed carbon inverted arc lamp which burned about 70 hours per trim and ran from 20 to 75 lamps per circuit. We now get from 1,000 to 12,000 hours life from the type C lamp, which life varies sometimes with the smashing point and in other cases with the burnout point of the lamp, and we are able to carry from 40 to 150 lamps per circuit.

We keep a continuous operating record of every lamp on the system, a record not only of the lamp itself but also of the apparatus which serves each particular lamp. We have three types of continuity equipment, the film cut-out system, the compensator system, and the series-multiple transformer system. The lamp record, which consists of a card for each particular standard throughout the system, shows the location of the standard, type of filament, make of lamp, date of installation, date of burn-out or breakage, and other necessary information on the face of the card, while on the back of the card we record the electrical

characteristics of the transformer, compensator, or film cut-out which serves the lamp. We can often forestall trouble by renewing some part of the apparatus that seems to be becoming defective, thus effecting certain economies which are shown in the decrease in operating costs; the cash cost of operation being now nearly 50 per cent. below the cost of the original arc lamp which we had in service some five years ago. The lamp card record is filled out by the sub-station operator who is assigned to the duty of taking care of this particular part of the system, his information being obtained from the trimmers' report sheet of the previous day. The trimmer in going out in the case of ordinary operation fills in his preliminary daily report from information obtained from the patrolman's report. This sheet shows the location of the standard on which any burnt out lamp is installed and also the type and make of lamp as well as the other characteristics of that particular unit at that location and date. These report sheets are made out in duplicate, one being retained by the operator in charge of the records, the other copy being taken out by the trimmer and turned in at night as his daily report. The data pertaining to the various burn-outs, breakage and things of that nature are transcribed in the evening by the operator on to the lamp card and the life data added as described below. The lamp life is calculated to the nearest tenth of an hour by reference to "progressive total hrs." records accurately kept from day to day, and to records of cutting in and out of the circuits.

In regard to breakage we have a more or less peculiar situation. We use 20″ Alba globes which are dangerous to handle from the top of a tower wagon, especially in bad weather. To avoid expensive breakage, as well as accidents to employees, we employ specially trained men who handle only this type of installation.

During 1918 we had 263 globes broken, amounting to 16.1 per cent. of our total installation, and during 1919 we had 171 globes or 10.45 per cent. of the installation broken, this breakage being occasioned not only by the regular operation and handling of the system but through malice in the matter of throwing stones at the units and breakage from automobiles, teams, etc.

We clean the globes with dry rags or waste saturated as a rule with alcohol where any sticky substance is on the globe. We do

not try to follow an absolute set rule in cleaning globes but we do try to keep them clean at all times. At certain seasons of the year, the small transparent Lake flies come in shore and they settle in droves on the globes during the night. In some cases it is impossible to see the globe on account of them. Their bodies stick on the globes and melt. Apparently there is no ordinary solvent for the material thus deposited on the globes and it is necessary to scour the outside of the globe with wet sand in order to remove it.

Another peculiar thing occurring on the Lake Shore is the filling up of the compensators, sockets and the interior of the globes, sometimes in the course of a week, with spider webs and spiders. We have found as many as two or three hundred spiders inside of one globe. The trimmers with their equipment are transported on electric tower wagons, equipped with an air tank that is filled up some times two or three times a day at the Power House to a pressure of 105 lbs. These tanks are equipped with small air hoses running to the top of the wagon and terminating in a very small nozzle which the men insert in the globe and blow out all foreign matter. We are able to blow down as many as fifty to sixty lamps with one charge of air and in that way we absolutely clean out the inside of the globe, the compensator, socket and the lamp itself.

We find in recording the data on these lamps that there is quite a variation in different makes of lamps and have tabulated data and plotted curves showing the variations.

Our circuits are arranged to light each particular street, boulevard, or park interior as the case may be; some times the boulevard may have a circuit on one side and another circuit on the other side which we call the straight circuit. In other cases the lamps on the circuits are electrically staggered, that is, the first lamp on the left of the street will be on current No. 1. The parallel lamp on the other side of the street will be on circuit No. 2. The next pair of lamps will be the exact reverse of the first pair. We find that the staggered system gives us a much better distribution of light in case one circuit is out. Some of these circuits are operated up to midnight, others are operated all night and still others are operated alternately one night up to midnight and the next night all night.

A very peculiar thing was discovered in regard to the life of lamps operating under these various conditions when separately tabulated. For about three years we tabulated the life in hours on certain lamps that were installed opposite each other on the same date, those on one side operating until midnight, and those on the other, all night long. It was found that two lamps installed on the same date, on opposite sides of the street would fail on an average, at about the same date, although one had burned a good many hours longer than the other. This appeared to indicate that the life of a lamp depends very largely on the number of times it is cut in and cut out. This conclusion seems to be borne out by the fact that on our series system most of our trouble is due to offseting of the filaments of the lamps.

Another problem which we have along these boulevards is the safety island lights. If these lights are out, the islands become obstructions which are decidedly unsafe. On each island we have a group of eight lamps in a top globe connected to two series multiple transformer circuits, and at the bottom of the post we have two base lights, one in each of the circuits described, so that if one circuit is out the other will still operate. We have on these boulevards the heavy buses of the Chicago Motor Bus Company, as well as many other machines, cause heavy vibration, and we have found that carbon lamps or the original type B lamps do not give good service. We therefore use 10 56-watt railway lamps on our posts.

We clean island lights at the same time that we clean the rest of the system and in the same way. For instance, a trimmer in the morning finds the patrolman's report which shows that in his assigned trimming territory, there are a certain number of lamps out. He goes out and replaces these lamps, and takes care of any trouble which may have occurred on the pole tops due to these burnouts. He is not allowed to handle anything alive nor below the pole top in the matter of trouble. He then begins to clean globes and continues until quitting time, the average according to weather conditions being from forty to seventy lamps cleaned per day. We get around to every lamp on the system except in case of trouble or extremely cold weather, about once every two weeks. There is a lamp maintenance man on duty at all times during the day and patrolmen on duty for sixteen hours

of each day. We find that by working the patrolmen, the operators and the trimmers in conjunction with each other and dovetailing their work we have absolutely no trouble at all in taking care of the record system in the matter of reporting and repairing defects or damage of any kind. The maintenance of circuits is taken care of by cable men, linemen, etc.

The lamps when they are brought in are subjected to exactly the same test as the one that Mr. Nixon mentioned. They are given a five minute rack test. Defective lamps are thrown out and returned to the manufacturer for credit. In the five makes of lamps which we have used in the five years that this type C system has been operating we find that in no case totaling over a years' run have the manufacturers fallen down on their average life guarantee. We find that there is quite a variation in the total average life. We have had a constantly increasing lamp life from the time this system was started which is now running somewhere in the neighborhood of 2,800 hours. As I said before on the old arc lamps the life was about 70 hours and it is apparent on the face of it that this means quite an economy.

Superficially observed, the matter of cost would seem to be dependent to a great extent on the life of the lamp. We find however, that although it is not necessary to renew lamps every 70 hours the men are released for other work, during the time thus saved and are enabled to keep the system much cleaner. We were able to reduce our trimming force only one-third when we changed the system over and while we get a great deal more light on the street we find that the increased cost of labor alone, is holding the cost of labor to what it was before the change. All things considered, at the present time our cash costs are about 60 per cent. of the cost of operation of the arc lamps under similar conditions.

The locating of lamps along the boulevard is done by means of intersections, and in the parks by rotation number entered on a map. The lamp maintenance men keep in touch with headquarters every hour by private telephone, eliminating expense and inconvenience.

In case of trouble on any particular circuit the trimmers and the lamp maintenance men are told to keep clear of the circuit in trouble. They are barred from that circuit for the day or until

such time as they receive the report that the trouble is cleared and there is no danger of high tension being thrown into the lamps at the location they are working on.

We find that the keeping of globes clean along the boulevards corresponds with the experience of other people. We have more trouble in the summer than we do in the winter. Naturally there is less dust and fewer insects in the winter but outside of that we are able to keep them just about as clean in the summer as we do in the winter by means of the air tanks and the other methods of cleaning I outlined above.

GOOD LIGHTING IN THE SCHOOLS.*

BY F. C. CALDWELL.
Professor Electrical Engineering, Ohio State University.

In studying a subject of this nature it is well to begin by drawing in a background against which to view it. In this case there are two considerations which may be embodied in such a background. For millions of years the human eye has been developing, but only during most recent times has there been, for the great mass of the people, any need for long-continued application of the eye to the discrimination of fine detail. What proportion, of the people of this country or of England, were able to read two hundred years ago ? And of those, who could do so, how many spent even one hour a day in the close application of the eyes to such a use ? Add to this small number the very few who were engaged in fine industrial occupation and you have the sum total of those whose eyes were in any danger of being strained.

Thus it appears that right at the present time, as it were, the average human eye is being called upon to adapt itself to conditions entirely different from those under which it has worked throughout all previous time. As one writer puts it, the case is not one of evolution but of revolution. Even now the extensive use of the eyes for fine work is confined for the majority of men to the period of their education.

The other consideration which may be included in the background of the picture has to do with the relation of the eye to the use of artificial illumination itself. While the use of tiny, flickering lamps goes back some hundreds of thousands of years to the days of the stone age cave dwellers of Europe, it is only during most recent times that light sources have become large enough and inexpensive enough, to make possible their use for any considerable amount of work by an appreciable fraction of man-kind.

Thus, after many generations of comparative ease, the eyes of the average man are suddenly obliged to adapt themselves, not

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only to much increased discrimination of fine detail, but at the same time to become accustomed to working under artificial light. This is a double burden which should be eased by every practicable means, and the first of these to recommend itself, is good lighting.

Nor need we be satisfied with general considerations such as the foregoing. It is a well established fact that during the years when the child is going to school the eyes are still in a somewhat plastic condition and likely to be deformed by use under unfavorable surroundings. For example, insufficient illumination tends to make the student stoop lower over his work, thus promoting short-sightedness, to say nothing of round shoulders and cramped lungs.

Abundant data is also available to show the actual results of improper conditions of study. Curves were given by Professor John Widmark at an International Congress on School Hygiene in 1913 and reproduced in TRANSACTIONS of Illuminating Engineering Society, Vol. X, page 182, as indicating the increase in eye defects from grade to grade in the schools of Sweden. These brought out most strikingly the real evil that has to be dealt with. Professor Widmark also gave a curve showing a steady decrease from 24½ to 17 in the percentage of short-sightedness during a period of eleven years, the improvement being due to care and improved surroundings. In my own city of Columbus tests of 4700 children made some 33 years ago showed 20 per cent. of defective eyes in the primary grades, but 33 per cent. in the senior high school class. With this may be compared the following data furnished by the office of the Superintendent of Schools. These figures relate to the results of examinations made upon the school children, chiefly in the lower grades.

Year	Number examined	Per cent. of persons needing glasses
1914	23,356	26.3
1915	17,249	14.5
1916	25,010	10.3
1917	8,970	10.3

These figures do not include the children who were already properly fitted with glasses. This fact accounts for the great drop between 1914, the first recent year when examinations were

made to 1915, in which year the figures of 14.5 per cent. would represent approximately the number of new pupils with defective eyes coming into the schools.

Though it may include a larger proportion of the pupils, the figures of 26.3 for 1914 may be roughly comparable with the 20 per cent. in the lower grades of 33 years ago, and does not make probable much improvement in eye conditions during a third of a century. This situation was also summed up by Cohn, thirty years ago in three laws which bear his name:

(1) The number of short-sighted pupils increases from class to class.
(2) The average degree of short-sightedness increases from class to class.
(3) The number of short-sighted pupils increases with increase of school demands.

One authority claims that only5 per cent. of the cases of myopia or short-sightedness are due to unpreventable causes.

Young children also experience greater difficulty in maintaining the tense muscles necessary both to focus the eyes on near-by objects and to converge them, so as to bring both eyes to bear on the point of interest.

The trouble from these various sources of eye-strain do not stop with the eyes themselves, but bring in their train headache, nervousness, irritability and retarded progress. It is to be borne in mind that the young child ordinarily does not know what the trouble with him is, and the teacher may also fail to correctly diagnose it. Thus a child who cannot see properly, will often be charged with stupidity.

While poor lighting is certainly not to be charged with all of the increase of eye trouble, it is unquestionably an important contributing factor. Furthermore the very fact that this unfortunate condition exists, makes more urgent the need for good lighting; for the defective eye has even greater need for proper illumination than the normal eye.

In general the reasons for good lighting can be considered under four headings, hygiene, safety, comfort or pleasure, and accuracy and speed of perception. Hygiene we have considered. Safety perhaps does not play as important a part in the needs of school buildings as in some other classes of lighting, but it

must not be forgotten. It is especially important that the lighting of stairways be ample so as to reduce injury from falls to a minimum. Pleasant and cheerful surroundings in which good lighting plays so large a part are certainly as much needed for school children as for any class of people.

The remarkable tests made by Mr. Durgin of the Commonwealth-Edison Company of Chicago, in which he showed that improved illumination resulted in increase of production in various industries ranging from 10 to 33 per cent. are well known to you. It will be remembered that in these tests the change in illumination was from an intensity that would ordinarily be considered quite satisfactory to one three or four times as great.

The results of these tests would seem to be immediately applicable to the manual training and other similar rooms in a school-building, and to have especial weight in view of the importance of developing habits of rapid and accurate work. It is interesting, however, to speculate on whether increased illumination generally in school rooms might not result in speeding up the accomplishments of the students, a thing usually much to be desired. I am not aware that any investigations of this point have been undertaken. It is, however, well established that retardation may result from eye-defects; the economic aspects of this were covered in the following quotation from a paper by Dr. L. C. Wessels of the Philadelphia Bureau of Health. The figures given are based on pre-war-times cost.

"In Philadelphia each pupil costs about $35 per year to teach. Under normal conditions a pupil 14 years of age should reach the eighth grade at a cost to the state of $280. If on account of defective vision the child only reaches the fourth grade in that time it has still cost the state $280, but with only $140 worth of result, a loss to the State of $140. The loss to the child is considerably more because at the age of 14 it is likely to be put to work, poorly equipped, with its earning power curtailed for want of a proper education so that it can contribute but little toward its own support or that of the state. So again the state loses." From this data it appears that it would not take much speeding up of the students with defective eyesight alone, to pay for the best of lighting, not to speak of any possible effect on the work of those with normal eyes.

As bearing on this point it may be mentioned that Mr. S. E. Doane, President of our Society, has recently devised two demonstrations which show in a striking way the increased accuracy and quickness of perception resulting from relatively high intensities of illumination. For the former purpose an ordinary chart with different sized letters such as is used by opticians in eye testing is employed. For quickness of perception an unknown letter is flashed past a hole in a screen.

It is hoped that in the near future some quantitative data may be obtained from tests such as these, which may have a bearing on the economics of good lighting in schools.

If then it be granted that good lighting is of more than ordinary importance in school buildings we face the question:

What is good lighting for this purpose?

In our answer we are fortunate in having at our disposal the Code of Lighting School Buildings, put out by the Committee on Lighting Legislation of the Illuminating Engineering Society. It is perhaps not necessary to repeat in detail the specifications found in this code for good school room lighting. A table of intensities for the different rooms usually found in a school building, is given, similar to that in the now well known model code for industrial lighting originally promulgated by the same committee. In addition to this, rules are given for avoiding glare, and undesirable contrasts and shadows, for the finishing of the walls and ceiling, controlling switches, emergency lighting and maintenance, corresponding to the appendix of the Industrial Lighting Code, there are several pages of "Notes, data and recommendations," and several good photographs showing examples of good and bad school lighting. This Code is strongly recommended to all who are in any way interested in this subject.

Proper natural lighting is, of course, of the greatest importance in school buildings. As a rule this is not difficult to obtain and most modern construction is fairly satisfactory in this respect. There are a few considerations of especial importance in this connection. A ratio of window area to floor area of at least one-fourth or one-fifth is well established; also that the light should come from the left side of the students and that there should be no windows in front. This brings up the interesting

question as to whether consideration for the teachers eyes should also dictate no windows in the rear. It would seem unfortunate, however, to have to close up the windows in one side of a corner room. My own experience with lecturing in such a room is that, if proper shades are available, such drastic measures are not necessary.

That windows should be situated as near to the ceiling as possible so as to throw the light into the farther side of the room, is a principle which sometimes conflicts with the architect's ambitions for exterior appearance but which should not give place to such considerations. The hanging of two shades at the middle of the window, one to pull up the other down is a most desirable arrangement, permitting excellent control of the light and the opening of either the upper or lower sash.

The question of daylight should be more in the mind of the architect when the building is being planned than is often the case. Questions of orientation, so as to avoid placing study rooms on the north side as far as possible and in cities to obtain adequate illumination in spite of surrounding buildings should then be considered.

Some authorities on school building construction have been disposed to consider artificial illumination as of minor importance, on the ground that so little of the work of the school is done after dark. The school hours were, however, chosen in the old days of inadequate and costly illumination, and now when artificial lighting can be readily made as good as, or in many cases even better than natural lighting, the inclusion of some of the hours of darkness within the school curriculum is to be expected at least in the case of the higher classes. Furthermore, the increasing use of school houses as community centers during the evening is certainly in keeping with the spirit of the times. In any event a school house is built to serve for many years, and, especially in these times, no one can tell what future uses it may include.

But even with the present schedule there are many hours during the year when daylight fails, and at such times, if artificial light is to be used at all it needs to be of the best. Dr Bell even states that in Boston, to avoid mixed light, it is customary to pull the shades whenever the daylight becomes insufficient.

Finally it is unlikely that any high grade school building would be built in these days without some sort of illumination, and if any is to be supplied the difference in the annual cost of the very best and the very poorest is so slight as not to demand serious consideration.

A detailed study of the lighting of all the kinds of rooms found in a modern school building would occupy more time than we have at our disposal and furthermore would hardly be of interest except to the man about to design such a lighting system. Some general considerations, however, may well be taken up.

What should be the general grade of illumination? In the various work rooms the I. E. S. Code gives a range of a minimum "ordinary practice" values from 2 to 6 foot-candles and a range of maximum values from 4 to 12 foot-candles. Should the lower or the higher values be used or does the trend of the times indicate still higher values?

From the point of view of safety and of hygiene so far as the normal eye is concerned, the lower values would probably be adequate, they are somewhat higher than the proposed minimum legal values of the code, and they agree quite closely with most of the values hitherto recommended for school lighting. For the subnormal eye it seems doubtful whether these values are high enough to reduce eye strain to a minimum.

It is, however, mainly from the point of view of the economic value that the use of higher intensities would seem most likely to be justified. If it is, indeed, possible to increase the speed and accuracy of accomplishment, even a little, by the use of intensities such as the upper ones given in the code, or perhaps even higher than these, they would be amply justified. Attention may again be called to the slight addition to the cost of operating a school involved in, say, doubling the electric light bills. The situation is analogous indeed to that found in a factory, where the cost of lighting, figured as a per cent. of the total cost of production, becomes very small.

Another question that would permit of much argument is with regard to the best type of fixture for use in the school study rooms. If these rooms could be looked upon only as work rooms, and the æsthetic element left out, we might follow the practice of factory lighting and use enameled reflectors of the most ap-

proved form. Indeed between such reflectors with ample light and many supposedly ornamental fixtures now in use the former would certainly be preferable. In the school room, however, where the aim is to cultivate the æsthetic sense, as well as to train the mind in other ways, such fixtures would not ordinarily be satisfactory. The choice would therefore be between high suspended direct lighting with some form of glass reflector, or semi-indirect, or indirect units. Very satisfactory lighting is insured by the use of either of the two latter, especially if, in the case of the semi-indirect, bowls of dense opal glass be used. Also it should be noted that, as the required intensity of illumination increases, the difficulty of getting away from glare with direct units becomes greater.

Excellent samples of school room lighting by the indirect and the semi-indirect methods are shown in Figs. 3 and 4 of the "Code of Lighting School Buildings," of the Society. The absence of glare and the uniform illumination is conspicuous in both of these examples. That good results can also be obtained with direct lighting is seen in Fig. 2 of the Code, which shows what adequate height and proper selection of reflectors will do.[1]

Contrasted with these is the case of Fig. 5 of the Code, where low hanging and too translucent shades combine with insufficient intensity to give a very poorly lighted room.

Due consideration should, however, be given to the fact that from one and a half to two times as much light can be obtained with the same expenditure of energy by use of the direct as by the semi-indirect (dense glass) or the indirect. The excellent results obtainable with these latter systems cannot be questioned, but the cost must be reckoned, and their advantages should not be purchased at the expense of insufficient foot-candles. To be more definite, 3 or 4 foot-candles with direct illumination is generally to be preferred to 2 foot-candles with semi-indirect or indirect, but it may be doubted whether 6 to 8 foot-candles of the direct is better than 4 of the other types. Doubtless 8 foot-candles of semi-indirect or indirect would be the best of all, but that it would always be worth what it would cost has perhaps not yet been demonstrated. Where indirect or semi-indirect lighting is used, the maintenance of very light colored ceilings and upper walls, which is always important, becomes much more essential.

[1] Code of Lighting School Buildings See Vol. XIII, No. 3, TRANSACTIONS I. E. S.

This brings to the front the never-to-be-neglected subject of glare. Few can be found to question the proposition that more lighting systems at the present time are notably bad because of glare than because of insufficient foot-candles. The general system of lighting, in which the lighting units are near the ceiling, is the only form that should be considered in school rooms, for whatever purpose used. Using this system, and in spite of the high brilliancy of present daylight sources direct glare from the lamps should be easily avoided. An exception to this may be the case where high intensities are attempted with direct lighting. Two very different examples of bad local lighting are shown in Figs. 6 and 7 (Code Figs. 6 and 7). In both of these the glare not only from the lamp at the table or machine in question, but also from neighboring lamps is serious.

Glare, however, due to the reflection of bright light-sources from black-boards, polished table-tops and glazed paper should be carefully avoided. To this end all polished and shiny surfaces should be eliminated as far as possible and where direct lighting units are used, the lamp filaments should be concealed by frosting or other devices. The lower part of the walls, as high as the top of the black-boards, should be finished in a medium tint, restful to the eyes. This is especially important in class rooms to avoid contrast with the black-boards. For the same reason these boards should not be placed between the windows. A system of black-board lighting by lamps placed in a hood along the top is to be recommended.

Dr. Bell, who was a pioneer in the scientific lighting of schools, recommends a somewhat eccentric location of the ceiling lighting units. By displacing them slightly toward the left and front of the students, he avoids shadows from the hand and head.

One of the most important aspects of good lighting in the school house is its bearing on good lighting in the home, a matter of greater moment and more far reaching for good or evil. The child who has been used to high intensities of well designed illumination in the school, will be a strong proponent of improvement in the lighting of his father's house; thus not only benefiting himself, but at the same time all the other members of his family.

Again the example of good lighting in the school, especially if enforced by some instruction, will make him more insistent on,

and appreciative of, good lighting when he has finished his school career and taken his position in the work of the world. In particular, if he has worked under a fine system of general illumination in the school he will be less likely to insist on local lighting for his work at the desk or bench.

Before taking up other phases of the subject, it will be well to sum up the situation with regard to the needs for and methods of illumination of school buildings. We have found first, that the present demands upon the eyes of school children are, from a biological point of view, revolutionary in character and call for every precaution to prevent the development of short sightedness and similar defects. The question of the economics of good lighting is worthy of further study. The Code of Lighting of School Buildings is recommended as the best available authority on the principles of school lighting.

Because of the longer hours of its use, proper natural illumination is of major importance and should be carefully arranged for in the design of the windows. While relatively few hours of the usual curriculum of the school require artificial illumination, the importance of good conditions during these hours, as well as the increasing use of the school buildings for other purposes, emphasize the advisability of a thoroughly high grade system of lighting. With regard to the grade of illumination to be provided, to insure ample light for the student with defective eyesight and also with the hope of increasing the speed of work generally, values at least as high as the maximum given in the Code are recommended. In the selection of a system of lighting the avoidance of glare is of great importance, especially where high intensities are used. The finish of the walls and ceiling must receive consideration. Finally the importance of good lighting as an example to the student is emphasized.

So much for the lighting of the school-house; there remains, however, the other relation between the school and good lighting wherein the school instead of being lighted becomes the source of enlightenment to the rest of the community. In former times the function of the school was to teach certain phenomena of light and certain characteristics of the human eye, but in these days of emphasis on the school as a training ground for living, it is easy to understand the importance of making certain prac-

tical deduction from these laws of light and physiological functions of the eye, which will make the students better able to provide themselves with proper illumination and better qualified to adapt it to the hygienic use of the eyes. However, this particular phase of the application of science to life has lagged behind other similar studies. This seems unfortunate when the delicacy and sensitiveness of the eyes is considered and when their importance to most men in the earning of their livelihood is taken into account.

This lag is probably due to the fact that the science of modern illumination is such a new one, and is changing so rapidly that it has not yet reached down to writers of school text books and to the teachers in the schools. A recent investigation of the text books on elementary science and hygiene for the grade school pupil brought out some interesting data. One of those that gave the most attention to illumination, about 17 pages, dismissed the electric light with three lines, while devoting nearly five pages to other illuminants. Another had about three pages on illumination, but nine other works had little or nothing on the subject. Nearly all that was given was more or less out of date.

The Committee on Education of the Illuminating Engineering Society has taken this situation to heart and is planning a campaign which it is hoped will bring this matter to the text book writers and teachers of the country in such a form as will result in an entire change of these conditions.

There are so many points of contact between the study of good lighting and the school curricula, that it would seem only necessary to arouse the interest of the teachers, and to get the necessary information into their hands, in order to bring to the study of illumination, the attention which it deserves.

While certain elementary facts, as for instance, that one should not sit facing a bright light, may properly be taught to even the kindergarten pupils, the first considerable study of the subject would seem to come very naturally in the courses in elementary science, hygiene, and similar subjects that are now quite generally given to classes just preceding the high school. It is here that we hope to get the best results.

Then there are also the courses in domestic science and physics in each of which some instruction on the principles of good light-

ing could with great propriety be taken up. In the study of physiology the effects of light upon the eye should be more emphasized. Even in chemistry the photo-chemical reactions in the eye might bring in useful lessons on the relation of intensity of light and rapidity of reaction.

There can, however, be little hope of getting any general results until we succeed in impressing the importance of the subject on the writers of text books and upon the teachers. It would appear that it should not be difficult to interest the former. When that is done, but probably not till then, we may hope to get the matter effectively before the schools. In the meantime, something may be accomplished in the case of individual teachers throughout the country by such meetings as this to-night, and by similar talks at the various educational meetings.

There are many members of the Illuminating Engineering Society who are competent to speak upon this subject and surely anyone of them would be willing to do so. It is to be hoped that there may be many meetings in the future to discuss "good lighting in the schools."

DISCUSSION.

Mr. Tillson: Is it true that some of that short-sightedness shown in the table is due to the fact that it refers to city children rather than country children? I have heard that out West where people live in a prairie country, outside of the towns, that the eyes are adjusted for long distances, and short-sightedness is not so pronounced as it is in the cities.

Mr. Cravath: Some of you will remember the tests that were run by Mr. A. J. Sweet for information on postal car lighting in 1912. The method used was to start with a low illumination and raise it gradually until the man who was reading said that he had enough to read by comfortably. The specifications adopted were 2.8 foot-candles minimum. It is well known that daylight illumination drops off very rapidly from the windows to the far side of the room, and I think the increasing use of the foot-candle meter has been enlightening, especially enlightening in connection with daylight, because we are very apt to think of daylight as what we are getting near the windows, and forget what is happening a few feet away. It is my experience, even

on such well lighted places as railroad trains, for example, in daylight the illumination on the seats next to the aisle is surprisingly low sometimes.

In the artificial lighting of our public schools in Chicago (and it is probably true of other cities) there is a situation that we should all seriously consider. Quite a large percentage of our school rooms are not used much at night, and consequently the authorities so far have felt that a great investment in lighting equipment was not justified. However, as good lighting has been getting relatively cheaper in the past few years, it hardly seems to me that the difference between a good diffusive lighting system and some of the glaring direct systems would justify sticking to the glaring systems, and that we should all of us use our influence to get away from the glare as much as possible in school room lighting. We have all of us seen some very remarkable examples of glare around this building this evening in school room lighting. I don't think we ever saw anything quite equal to what is going on down in the test room in the way of glare, where students are trying to listen to a lecture under a lot of low bare gas filled lamps.

In this connection it cannot be said that the expense is in the way of improvement because there are a good many things short of a thorough over-hauling that can be done to relieve glare conditions where appearance don't count for much. There is more than one way to make a reflector and get diffusion, and some little simple devices can very often be used to tide over for a few years, and help out a very glaring situation, if only some of the engineering talent a school like this is supposed to develop is applied to the matter.

Mr. Scheible: I was quite impressed with a number of points that Professor Caldwell touched on. For instance, the difficulty of getting comparative figures or charts was brought out by the Swedish chart and the figures he quoted from some Columbus tests, because the standards are apt to differ, and the local conditions may differ, not only from urban to suburban or rural life, but also in other ways. I presume the forms of type or print would not make so much difference between Sweden and this country, but I recall seeing some figures based on tests made in

Germany where undoubtedly the greater difficulty of reading the type as commonly used there, had quite an influence.

Then, again, we have here the average figures, regardless of the manner in which the pupils were seated. It reminds me of some figures that I saw recently as to the comparative standing of pupils seated within easy hearing distance of the teacher or lecturers and those that were further back and had to strain themselves more. If similar tests were made in school rooms, comparing the pupils that had the better lighted portion of the room and the others, these might show a corresponding difference.

Professor Caldwell also touched on the economic aspects of school lighting as distinguished from the hygienic and I think that is a point which should be brought home to people more generally. The hygienic aspect is so often looked upon more or less as a fad, but when you get down to the dollars and cents, the school authorities or boards are more apt to listen to you. For example, if you can show that when inferior lighting makes it so much more difficult for a pupil to grasp his work and causes him thereby to drop behind a year, and that this means an added cost of thirty-five to fifty dollars a year to a community, the point will come home to our school boards much more than the question of hygiene.

Then Professor Caldwell touched on the fact that usually all other plans are subsidiary to the architect's artistic ideas. He gets his general idea of the exterior of the building first, and everything else has to conform, which is not true in all other cases of planning, and which should not be the case for effective school lighting. Years ago a classmate of mine had been doing a variety of architectural work right across from me, and I asked him whether he could tell what was the most difficult architectural task assigned to him. He replied: "Yes—decidedly—it was designing a car for the Wagner Car Co. They not only gave me the general dimensions, but they told me just how the berth was going to be located and even where I had to plan room for the bolts; and my artistic ideas had to conform to those dimensions." If we could get our architects to do the same, with such compromises as are really demanded for reasonably artistic effects, I think we would get far better results.

MR. ROGERS: The first thing I want to do is to welcome the Illuminating Engineering Society to the Lewis Institute, and the next thing I want to do is to thank Mr. Cravath for criticising the lighting.

Mr. Cravath especially criticised the room that we designate as Room 39. That is the dynamo laboratory, and this evening there is a class being held there. It is not ordinarily held there, but it was to-night, and this room is equipped with Type C lamps and glass reflectors about a foot above the lamps. Now those lamps that you saw there to-night replaced arc lamps which were in there two years ago. This I consider no improvement over the arc lamp.

I was much interested in seeing those figures on the chart about minimum illumination. Now this room that we are in is a hard room to light. The ceiling is low. Sitting back here you have to look right through lamps that are on the ceiling. It is a very difficult room to get good results in—and the illumination doesn't strike a casual observer as being very bad, and yet it runs only about two foot-candles directly under one of the lamps, in about the position where one is sitting. It is less than two foot-candles on the table, I believe, where those foot-candle meters are now lying, and over here next to the wall it is considerably less than one foot-candle, yet this is one of the best lighted rooms in the building. There are other rooms around here that have half a foot-candle in some places, and in other places not quite that much.

I wish everybody here would criticise as much as he pleases so that we can get the benefit of the criticisms.

MR. FOSTER: I don't know how to do it when you talk about constructive criticism. As far as criticism is concerned I believe if suggestions are in order I think that most any of us in the room here would be very glad of the opportunity to come out here and go through the school and offer suggestions for the improvement of each room, but how to cross the bridge, I don't know.

MR. TILLSON: We have at 66 W. Adams Street a few of the exhibits that Professor Caldwell has just shown us. Two industrial rooms have been fitted up. In one discarded and disreput-

able light and power methods are shown, and in the other we can get intensities of three, six, twelve, twenty-four, seventy-five and eighty-two foot candles. We use Snelling Charts as Dr. Caldwell showed, also, for quickness of perception an affair of this sort only equipped with a magazine which holds quite a number of letters, and they are dropped by gravity past a slot by pulling a cord. We test out the people who visit the place with different intensities, by having them observe letters dropping through that slot.

Another affair copied after the one at Nela Park is a glare demonstration where a one thousand watt lamp is brought up to full voltage behind a glass pane. Across the glass and surrounding the pane there is printing, and as the lamp comes up to voltage that printing is obliterated by the glare. If any of you are interested the rooms are open now to the public and can be seen at any time. It is on the ground floor just east of the Adams Street entrance of the Edison Building.

PROF. CALDWELL: Perhaps my point concerning the education of the pupils with regard to illumination, was not quite understood. It was not the education of the pupils with regard to lighting the school-houses but in the use of light generally, in the homes and everywhere else. Of course, it we could get correct ideas adequately spread through the community they would come around to the school boards, and would eventually develop a proper attitude towards school-house lighting but that would be a slow process, and other more rapid means of reaching the school boards are doubtless necessary.

THE NECESSITY FOR STANDARDS IN THE RELATION BETWEEN ILLUMINATION AND OUTPUT.*

BY WARD HARRISON.

Artificial lighting is often judged as good or bad depending upon the degree wherein it differs from the daylight conditions to which we are accustomed. Granting for the time that such a basis of evaluation may be a reasonable one, it is of interest to investigate the most usual differences between daylight illumination of interiors and its substitute. The two most common points of difference are: *first,* lesser diffusion of light—that is, small sources of high brilliancy causing glare and objectionable shadows as contrasted with the large light-giving areas of low brightness, such as the windows; *second,* lesser quantity of illumination both on the work and on adjacent surfaces. Inferiority in respect to diffusion of light although almost universal, is unquestionably a matter of neglect or of misapprehension of the principles of illumination, for to-day well diffused light costs little if any more than the other variety. On the other hand the question of the quantity of light to be supplied is usually considered to be an economic one. True, a certain minimum illumination is necessary to provide against accident, and should be supplied without regard to cost, and for certain operations a considerably greater amount than this minimum may be required to conserve the vision of the employees. In passing it may be noted that both of these factors are now recognized in the industrial codes of several states.

On the other hand, the experience of those who have investigated the subject most thoroughly is that in the majority of industrial operations it is not either one of the foregoing factors, accident prevention or conservation of vision, which should finally fix the quantity of illumination to be supplied in a given case.

In examining the works of a watch we almost involuntarily move over toward the window, although the illumination at all points in the room may be far above that ordinarily required

* Paper presented before a meeting of the Taylor Society at Rochester, N. Y., May 7th 1920, in behalf I. E. S. Committee on Reciprocal Relations.

to prevent eye strain. *We find that we can see more with increased illumination.* An examination of the Snellen's Chart under two degrees of illumination, say one foot-candle and ten foot-candles*, will serve to confirm this belief. Again, we all know that a late afternoon tennis match must stop long before the ball, stationary, has become invisible to the players. *More light is required when objects in motion are to be discerned, or, conversely, one's quickness of vision depends upon the degree of illumination supplied.* (The second simple demonstration is illustrative of this point.) Likewise, if, after an illumination has been reached under which we see both quickly and easily, the quantity of light is continually increased, it is reasonable to suppose that we will eventually come to the point where there is too much light, and where our ability to see is actually diminished thereby.

In reality, however, there is little likelihood of ever getting our general level of artificial illumination too high, particularly in view of the fact that average outdoor illumination on a cloudy day is something like 1,000 foot-candles (units of illumination) and that a snow field does not become uncomfortably bright until illuminated to perhaps 5,000 foot-candles. Artificial illumination in industrial plants usually falls between ½ and 10 foot-candles with a pronounced leaning in the direction of the smaller figure. Good indoor daylight is ordinarily considered to be not less than 15 foot-candles.

At this point the main thesis of this paper at once suggests itself. How far does it pay to go ? How many foot-candles should be supplied for a given operation in order that it may be conducted most economically, taking into account both the cost of the lighting and the possible increase in production and decrease in cost of manufacture which results from the change in lighting ? Such positive knowledge of the subject as there is now available may be expressed in a very few words.

* The foot-candle meter is a small, portable instrument which measures illumination directly in foot-candles. Since the foot-candle is rapidly becoming recognized as the popular as well as the scientific measure of illumination, this meter is a very practical measuring instrument. Technical knowledge of photometry is not required in its use because the adjustment is simple and determinations are made without the assistance of mathematical calculations. The foot-candles of illumination at any place are indicated by the point where the spots on the foot-candle meter screen change from brighter than their background to darker. The scale reproduced in Figure 3 indicates an illumination of 9 foot-candles.

First: Night shifts, or for that matter evening shifts are notoriously inefficient. Their production averages from 10 to 25% less than that of day shifts. The difference is due, in part at least, to the inadequacy of the lighting ordinarily supplied.

Second: In plants averaging, say 100 square feet of floor space per employee the cost of good artificial lighting per foot-candle supplied is usually not in excess of 0.1 per cent. of employees' remuneration during the period.

Third: It is the concensus of opinion that while good lighting, as well as all other hygienic conditions, is conducive to a willingness to do more work, the increased production resulting from improved illumination is not due chiefly to a stimulative effect, but principally to the elimination of those small losses of time, and aggravating interruptions in the work, which result from inadequate illumination.

Fourth: In all of the efficiency tests conducted to date the highest level of illumination investigated has invariably shown the greatest production and the greatest economy. In fact in the range considered, the relation of decreased production costs to total lighting costs is of the order of 10 to 1. Four such tests which were conducted in a thoroughly scientific manner under the supervision of Mr. W. A. Durgin show increases in production of 10 to 20 per cent. resulting from better lighting.*

In addition to the Durgin tests noted above, there have been several other less complete investigations in various industries which have also indicated substantial gains from the liberal employment of properly designed illumination. It is evident, however, that the imperative need of the art is for a far greater number of exhaustive tests covering many industries, tests which not only establish the range over which illumination may be profitably increased for a given operation, but, which are also carried to such a point of extremely high illumination that an actual decrease in economy is recorded due to the increased production, if there is any, being insufficient to compensate for the added cost of the light. All of these needs seem so simple and so obvious that you are inclined to ask why hasn't all this been taken care of long ago. The answer is that those interested in the subject of scientific illumination have been men trained in

* A record of these tests was published, *Electrical Review*, Chicago, March 22, [illegible]

improving the efficiency of our light sources and lighting units, and in designing better lighting systems. It is only through their efforts that artificial lighting comparable with daylight has become available and at a reasonable price. These men very properly look to those skilled in the science of management to co-operate with them in solving the second part of the problem; that is, in determining just what degree of illumination is desirable and profitable in a given industry. As Chairman of the Reciprocal Relations Committee of the Illuminating Engineering Society, I commend this subject to the serious consideration of the members of the Taylor Society, and assure you that if you see fit to inaugurate such tests in your own plants or in the plants of your clients, the Illuminating Engineering Society will be glad indeed to furnish you with the best technical advice on the design of the various lighting systems and the choice of equipment.

In an appendix to this paper there has been included a list of factors which have been found in previous tests to require particular attention.

APPENDIX.

1. The test should cover a considerable number of operators working in the test area, supplied with a uniform illumination.

2. A separate work sheet should be kept for each man.

3. The humidity of the atmosphere, the time of the year, the days of the week, and days before and after holidays should all be closely noted, as any of these may cause a variation in production.

4. There should be a number of different illumination steps employed in the test. It is preferable to start with the original system, and check back on this original system several times, as well as to check production at least two times at each level. A check should also be kept on the daylight production when possible.

5. The material supplied the men should be closely inspected, for at this time especially many plants have considerable difficulty in securing their rough products; rough castings may one week require finishing down 1/4″, and the next week the shipment may have to be finished 3/8″.

6. It is desirable that a knowledge that test is under way be kept from the men when possible.

340'

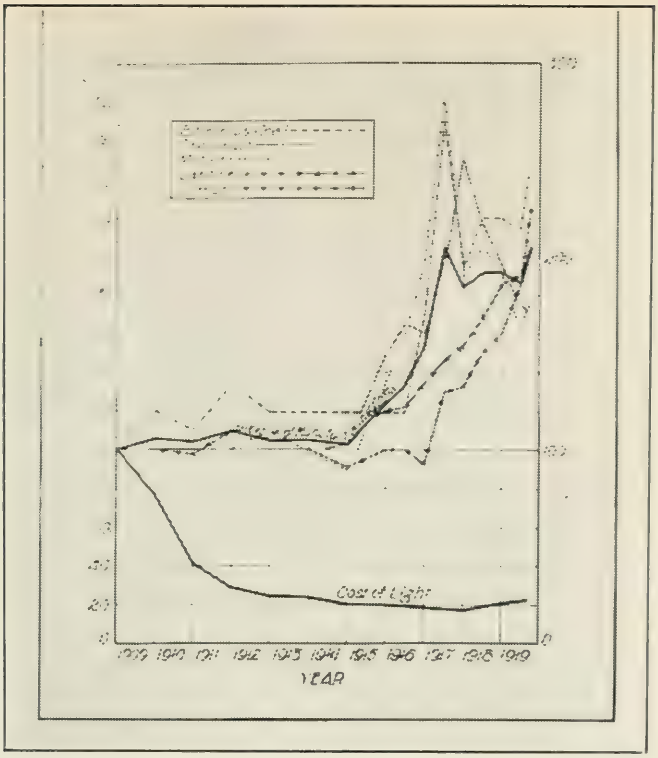


Fig. 1.—Cost of light as compared with other manufacturing costs.

Fig. 2.—Foot-candle meter.

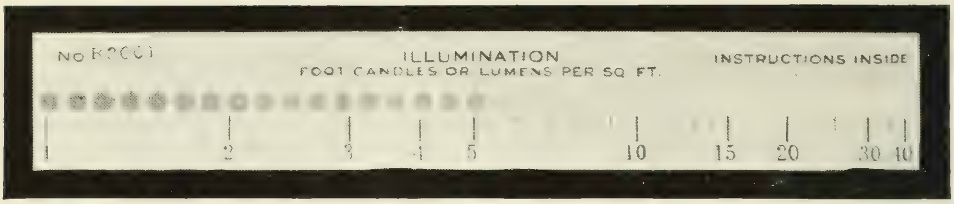


Fig. 3.—Foot-candle meter screen indicating nine foot-candles.

Fig. 4 —Well lighted room. Adjacent rooms in same factory.

340²

Fig. 5.—Poorly lighted room. Adjacent rooms in same factory.

Fig. 6.—Eighteen foot-candles for very fine work.

Fig. 7.—Two methods of lighting the same process.

Fig. 8.—Two methods of lighting the same process.

Fig. 9.—A correct method of office lighting.

Fig. 10.—Even at a mounting height of 40 feet it is possible to have good illumination

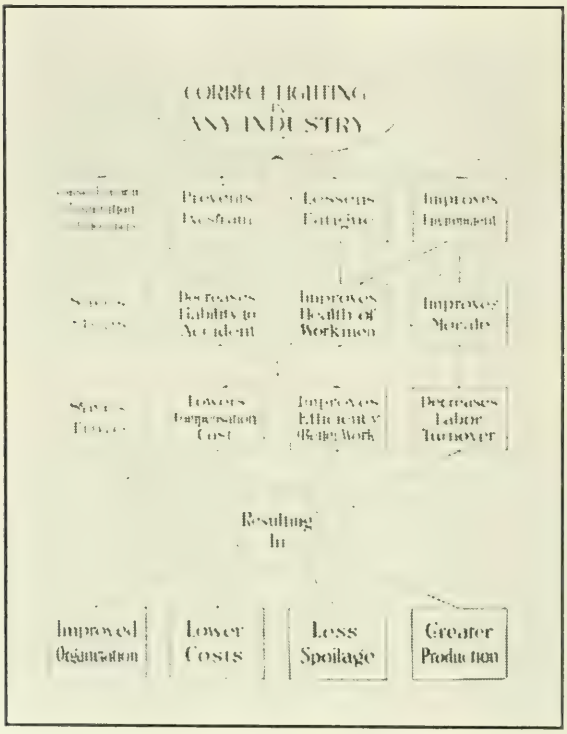


Fig. 11.—Correct lighting in any Industry. (Courtesy of Benjamin Electric Manufacturing Co.)

7. There should be a close supervision of the men at all times to see that they are all at work and to note any changes in personnel.

8. There should be a close check on the material supplied the men as well as the power supply, in order to note any shutdown from either of these causes.

9. Objection from the workmen is liable to be experienced when changing the size of lamps and reflectors, but this can largely be overcome by making all changes over the week-end.

10. The foot-candle illumination should be measured at the beginning and end of the hours under consideration as well as at certain intermediate hours. Definite stations should be located for these readings.

OPPORTUNITIES FOR THE ILLUMINATING ENGINEER IN THE MOTION PICTURE INDUSTRY.*

BY E. L. BRAGDON.

For our purpose this evening I have separated the motion picture industry into the following three distinct divisions.

First—Production or studio.
Second—Preparation or laboratory.
Third—Exhibition or theatrical.

It is the production or studio end of the field that the illuminating engineer first comes into direct contact with the motion picture, since sunlight has been found to be variable. The lighting units in use are eminently satisfactory and are surely in advance of the average director's talent for using them. So called "new lighting effects" are being evolved weekly, but they do not necessarily call for new lamps, or better lamps, but for a different technique in the use of lamps. A new high intensity white flame arc, has recently been adapted for studio use and seems to fill many of the needs for a lamp of wide utility. Another stand lamp developed during the last year or so and using a reactance control is claimed to give a slightly higher efficiency than its competitors. But under present day studio practice a few per cent. in operating efficiency means little. Dependability and ability to withstand the rough usage of electricians are more important considerations. If some illuminating engineer will please come forward with a method to tone up the efficiency of recalicitrant and temperamental stars of both sexes, we may for the time forget whatever inefficiency the lights may show.

The studio is one of the stopping points in this industry where the illuminating engineer is needed, but it is not the location of desperate need. That is elsewhere.

Considering next the laboratory phase we find that if it were not for the fact that this is an exceedingly important cog in the industry we might pass over it with a mere mention, for of necessity there is need in the laboratory for more darkness than of light. There have been problems, to be sure, but they have been solved quite successfully by a dark room light, devised by

* Paper presented before a meeting of the New York Section of the Illuminating Engineering Society, June 17, 1920, New York, N. Y.

the principal film manufacturer and now in almost general use. This device is merely a type of lantern suspended from the ceiling. The box may have the special ruby glass in one or more sides according to the nature of the work it is to illuminate, otherwise the box is light tight.

This leads us to the theatrical or exhibiting end; the phase of the film business that comes nearest to the public. It will be well for us to pause here awhile, for if ever any part of an industry needed expert aid, it is the exhibiting end.

There are really two fields in the theatre to be considered, that of auditorium illumination, and of projection. Each will be discussed in turn.

There are approximately 14,000 theatres in this country devoted to the motion picture. This number includes the "Palace of the Cinema" in the big city as well as the once-a-week-on-Saturday-night show given in the "Grange Hall" in some Wyoming cattle town. It is interesting to note that of the 14,000 theatres, over 65% or nearly 10,000 theatres have a seating capacity of 600 or less. This fact has been ascertained through research and records.

Six hundred seats, mean the community house attended by the general public. It is the place where public opinion regarding motion pictures is formed and for that reason this size of theatre is a good one to keep an eye on. It is also well to give the patrons of these houses the best available in-so-far as possible, and that is what they are not getting as regards illumination.

The illumination in these small theatres as a rule is exceedingly poor. Designed in most cases by a local architect or more probably a contractor the theatre is built and then the lighting scheme added as an accessory, much as a theatre manager goes out and buys his seats. A study of interiors of the average small theatre will often show that in one spot on the ceiling where an indirect fixture should have gone the decorator has thoughtlessly placed a beautiful figure of some dryad disporting herself. Naturally a lighting fixture must go elsewhere. According to practice, the decoration comes first. I don't know exactly why, because the patrons attend the theatres (at least after its opening night) to see the pictures and not to sit back and dream about the alle-

gorical figures on the walls and ceilings. I do not advocate the abolishment of decorations, they have a place of their own in theatres, but I do decry the placing of decorations before illumination for reasons which will be referred to later on.

You may also have noticed the persistency with which architects place candelabra brackets in every panel on the side walls. Invariably these shine directly into the faces of those in the balcony with serious effects on the vision. Why this is done, I do not know. The most plausible answer seems *imitation*.

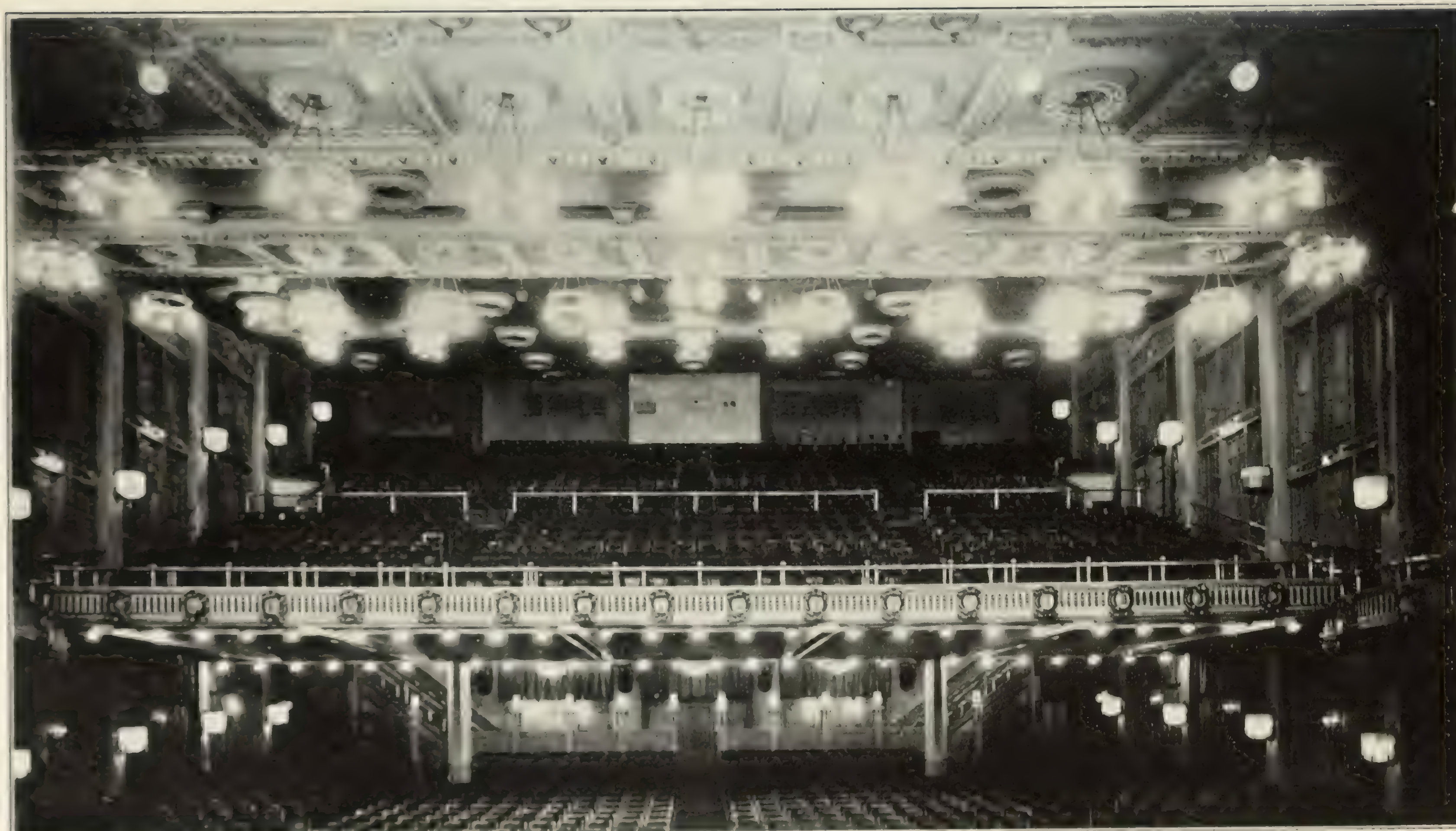
In general the theatres to-day are too well or too poorly lighted. This may sound like an aphorism but it is a fact nevertheless. It is rather strange too when you consider how simple it would be to travel the broad middle path of just about enough light.

Going back into the history of the industry it appears that the first motion picture exhibition was held in a store. When the audience had been enticed into the place the lights were turned out and the room made pitch dark. Then the show started.

This method of handling the illumination of the auditorium should have disappeared early. But it did not. Only last week I happened to enter one of Broadway's leading theatres and was greeted by as dense an atmosphere as one could wish. I stumbled over a floor ornament just inside the door and finally had to be led to a seat by a torch bearing Aurora. The absence of light in that theatre was positively painful. Broadway screens are lighted to a minimum from the projection arc and the contrast between the screen surface and the surrounding areas was exceedingly vivid. My companion went to sleep in the middle of the picture claiming that his eyes ached. It was easy to understand why.

Now, that theatre badly needed the services of an illuminating engineer and if it were not for the fact that anything "gets by" on Broadway, the manager's profits would soon show him that something was wrong.

To show the other side of the question the accompanying picture illustrates what happens when a motion picture theatre is built for beauty and not for motion pictures. The photograph was sent by a theatre manager who wished to show me what wonderful illumination he had in his theatre. I will let you judge for yourself.



Over Doing the Lighting of a Motion Picture Theatre.

It is possible that an electrical contractor *might* have put in a few more fixtures but I firmly believe that there must be a hidden beam or a ventilating duct in the spaces which are bare of lamps.

Seriously, the lighting of theatres is a real problem. It has been overlooked in the past. As a result the optometrists or the opticians are using the motion picture as an argument for the wearing of spectacles. This should not be. Moreover, it must not be for the good of the industry.

Without going into the preliminaries of the separate factors, the fundamentals of theatre illumination are as follows:

1. Keep as much light as possible away from the screen surface.
2. Present as little contrast as possible to the eyes of the audience when viewing the picture.
3. Make the transition from afternoon sunlight or evening "white way" lighting to the viewing position as gradual as possible.

A casual study of these broad principles will show that the perfect theatre whenever it is built, will have considerable illumination at the rear, decreasing gradually as one walks toward the front of the house. The light will be reflected chiefly from walls and ceilings with a minimum of direct illumination, and all the light must be so directed that the shadows of the screen are not veiled. This seems rather difficult, but it can be done, and will be done as soon as builders and architects realize the value of correct illumination.

This means that the present brilliant music stand lights of the orchestra will have to be moderated. Several ways of doing away with the evil of the orchestra light have been suggested, but none is conspicuous by its practicability. One man has even suggested the printing of the music score in radium ink on black paper, but his suggestion was not considered as of much worth.

I could go on in this manner for many minutes relating the abuses of illumination in the average theatre but the narrative would tire you. When all the facts are sifted to their essentials it is found that the whole problem is one of co-operation between architect and illuminating engineer.

A few words concerning the projection end of the theatre work are in order. This, of course, is also a problem of illumination. The problem is to get a steady and easily controlled, concentrated

source of light, of high brilliancy, and to pass through the standard optical system as high a percentage of light as possible. To give you an idea of the troubles encountered in the projector of to-day consider these figures; of 100 per cent. of light at the source:

> 25 per cent. reaches the condenser lenses,
> 80 per cent. of that reaches the film,
> 75 per cent. of that reaches the shutter,

and for good measure the shutter borrows 50 per cent. of that. Thus, only four-fifth of one per cent. of the original light reaches the screen. There are too many middlemen and each is a profiteer.

The illuminating engineer is needed badly here but the field is a special one in optics and will demand a great deal of work before much is accomplished. What forms these improvements will take would be but a surmise.

The incandescent lamp is a wonderful possibility. I have always had faith in it and feel surer of myself at this moment than ever before. It will not supplant the arc; each has its field and they are both big fields, worth cultivating in the right way.

In closing, I would like to emphasize the fact that of the whole industry the greatest need for the illuminating engineer, his theories and his experience, lies in the field of theatre illumination. As now carried out it is unsatisfactory and something should be done at once to correct the evil. On my desk I have a card index of new theatres upon which building has begun since the first of the year. Probably there are 600 of them and it is fairly safe to say that of these 600, 550 will be lighted the same old way without thought on the part of the owner and architect. Eventually it is to be hoped that the combination of illuminating engineer and architect will solve the whole problem.

ADDITIONAL COMMUNICATED DISCUSSION. SEARCHLIGHTS IN THE A. E. F.*

BY D. W. BLAKESLEE, E. E.

MAJOR ALEXANDER MACOMBER: I believe that the importance of the blinding effect of the searchlight beam on the aviator is greater than Lieutenant Blakeslee's paper would seem to indicate. The psychological effect of the beam on the aviator under the strain of combat conditions may seriously disrupt the enemy. Reports of our own aviators during the night pursuit work of the Meuse-Argonne operations indicate that this is true. With the modern searchlights now used by the United States Army the "blinding" effect is undoubtedly greater than that which resulted from those in use by the enemy during the World War.

After the St. Mihiel drive the importance of the training of night pilots with co-operation searchlights was realized by headquarters and detailed arrangements were concluded with the various headquarters interested and a definite scheme drawn up. At that time we were covering the entire American front with various companies stationed throughout the Second Army area and extending over the First Army area through the Meuse-Argonne. In order to develop experience in night flying, the 185th Squadron of the First Pursuit Groupe consisting of Sopwith Camels was assigned for the specific work of night flying in co-operation with searchlights. The territory for patrol was carefully divided and assignments made with the necessary landing arrangements, and in fact, one of the platoons was stationed at the aerodrome headquarters through the Argonne drive for landing assistance at night. Our regimental headquarters governed the operations of the various units of the regiment which were throughout the St. Mihiel and Argonne drives as well as with the British and French Armies.

* Printed in Vol. XV, No. 3, April 30th 1920, page 203.

** Commanding Officer 56th Engineers.

TRANSACTIONS

OF THE

Illuminating Engineering Society

PART II -- PAPERS

VOL. XV | AUGUST 20, 1920 | No. 6

ILLUMINATING ENGINEERING FROM THE SIDELINES.*

R. W. SHENTON.

Perhaps I should say at the outset that the viewpoint from which I am discussing illuminating engineering is that of one who is on the outer edge of it, rather than one remotely interested in what illuminating engineering has been and is doing for public welfare, and it is therefore very likely that before concluding I shall find myself dropping into the intimate first person plural instead of confining myself to the more distant third person. It is also likely that while I have in mind the subject of lighting in its broader aspects, the discussion will run very much to industrial lighting because the benefits of good lighting in this field have lent themselves especially well to analysis in definite, tangible terms, although they are no less real in other illumination fields.

Even men young in the art can carry their reminiscenses to a point where the words illumination and engineering first began to be linked together. At that time most of us shared hazy if not erroneous ideas in regard to this new profession. My own was that the illuminating engineer was some sort of central station specialist, qualified in all the steps of changing coal at the power-house into light at the customer's socket. It was a surprise to learn that this profession was made up of men primarily interested in light after it leaves the lamp as candlepower or lumens, rather than in the steps leading up to this point, and later to wake up to the important bearing, now becoming so obvious, that applied lumens have upon the whole social and economic order of things.

* Paper presented before the New York Section of the Illuminating Engineering Society, New York, N. Y., May 13th, 1920.

The illuminating engineer blazed a new trail, for while artificial light has been used for thousands of years, it remained for our own half-century to reduce to a science those things which transpire between the lighted lamp up there and the plane down here where we live our lives. The establishing of relations of cause and effect called for definitions of terms and for standards of values, as is always the case when an old subject evolves from chaos into order. Definitions seemingly involved and mathematical to a useless degree, made their appearance in the writings of the engineer. There were prolonged and tedious discussions on subjects that formerly no one but the physicist had considered worthy of more than a passing thought. It was those things that he saw and heard that gave to the man on the sidelines his impression of illuminating engineering. Failing to grasp the vision of the illuminating engineer, his impression was one of trigonometry and calculus—of nebulous theory rather than crystallized facts of positive value. He had a vague notion that glare was harmful, but why make such a fuss over it ? He knew that light was a good thing, but anybody could install lights without making a mathematical problem of it. He knew generally that "shades" of some kind over a lamp were a good thing, but why spit hairs over what particular kind should be used ? Why make measurements of illumination any more than specify the oxygen content of the air we breathe ? It seemed like taking the joy out of life.

I remember with considerable amusement an occasion when some four or five years ago the engineers of a lamp company had the temerity to suggest to the commercial people of this same company that henceforth lamps be rated in lumens rather than candlepower. Yet, once these units of measurement became established, they were able to throw off their mathematical scaffolding as having fulfilled its purpose, and ceased to be any more technical than the ampere, for example, which we very seldom think of in terms of its basic definition. Used in connection with statistics showing the influence of lighting upon the welfare of the public, on the street, in the office, and in the shop, foot-candles have slipped quietly out of the purely technical vocabulary into the more popular vocabulary along with carburetors and differentials and other erstwhile technical terms which the layman has

come to understand in terms of his own desire for a more abundant life. Illumination theories that have been propounded in engineering circles for years are now on the lips of the man of affairs—so much so, that the popular press has on a number of occasions taken up the subject of illumination in considerable detail and has not hesitated to use liberal sprinklings of "foot-candles," "lumens," "specular reflection" and so on, throughout the text—terms and allusions which in the past had been confined strictly to the class of articles known as technical.

The public has undoubtedly begun to adopt the language of the illuminating engineer. I have sat in meetings where factory superintendents spoke as glibly of foot-candles as they might be expected to speak of horse-power or time-clocks; I have heard of a department store manager who wishes to codify the lighting requirements of different parts of his store for different occasions in terms of foot-candles; a manufacturer calls up a lamp company by long distance telephone to find out whether, if he sends a special messenger that night, he can borrow a foot-candle meter for use the next day. There is a rapidly growing demand for men qualified to serve in permanent positions as lighting men. We need not look far to find the reason for this interest in lighting. The industrial manager has an interest in foot-candles because the state codes and insurance companies have given him a vital message in that language. A message in regard to the effect of light on production came to him, with foot-candles as the "X" on the unknown side of the equation and an "S" with two parallel lines drawn down through it as the first character on the other side of the equality mark. Your progressive business man recognizes that second sign, and, once the message commands his serious attention, loses no time in solving for X.

We are in the beginning of a new era in lighting. An era characterized by a new appreciation of lighting on the part of people who use it, which is removing lighting from the janitor class of service and placing it in the investment class, because there is a growing recognition that it pays dividends not only in better eyesight and better living conditions, in general, but in lives and limbs saved and dollars earned. The full force of statements made before this society to the effect that almost a quarter of our industrial accidents are due in whole or in part to inadequate

lighting, that our yearly casualties attributable in greater or less measure to this cause exceed our yearly casualty list of 250,000 during the recent war, is gradually soaking in. We are beginning to realize that whenever we see a man who has been a victim of an industrial accident, whether the evidence is an empty sleeve, a sightless eye, or a limb, that there is one chance in four that improper lighting had something to do with that man's condition. We are beginning to appreciate the significance of statements that manufacturers have increased their output ten, twenty, thirty per cent. by stepping to brand new standards of artificial lighting. In these days of high-strung operation, production men are looking for opportunities to reduce spoilage and increase output by fractions of a per cent. Along comes illuminating engineering, to distort a time-honored metaphor, and shows that it was the shadow of the camel that made it so hard for them to see the gnat. Not so long ago, a paper before this society advocated consideration of daylight standards of artificial lighting. It seemed rather a bold proposal at the time, because we had become accustomed to think that any approach to daylight intensities would be prohibitively expensive. Illumination has been assigned to its proper status, however, and to-day the thing is being done.

The layman has shown unmistakable signs of an awakening to the importance of the part that artificial illumination plays in his daily life. If anything he has shown a tendency to be too eager to grab and run, without waiting for all the facts, or, getting the essential facts, without properly assimilating them. He hears that lighting is a good thing, he sees a demonstration of good lighting and knows that it is a good thing, but fails to grasp the fundamental distinctions between good and bad lighting. He doesn't get the idea of how bad lighting really can be, or of how important some of the seemingly minor factors are in determining whether a system will be good or bad. The average man does not realize that lighting can be bad even though there is plenty of light and good lamps and good reflectors are used. The doughboy who had thought that a few parlez vous's, demitasse's, and tres bien's added to his vocabulary gave him a working knowledge of French, came to with a jolt when he tried to make himself understood on the other side. No fault is to be found with his ambition or the direction of his efforts in attaining that ambition,

except that he didn't go far enough. Recognizing the importance of illumination and adopting part of the vernacular of the illuminating engineer is not enough to give a man a working knowledge of lighting. He must carry his studies further as to what are the factors that enter into good lighting and must appreciate in terms of human experience the importance of these factors in the various fields of lighting.

A year ago there was staged in connection with the N. E. L. A. Convention rather an elaborate exhibit of lighting in its various fields. One of the displays, an industrial lighting demonstration, is of particular interest to us as showing to what extent the essential qualities of good lighting are entirely overlooked by the man who has not been specializing in illumination matters. This display consisted of a fairly large room made up to resemble part of an industrial plant. Three lighting systems, each of a different kind and grade, were switched on in turn and an opportunity given to study the lighting results under each. Visitors to the exhibit stood in the doorway and watched the successive changes, registering varying degrees of approval with each. When the best system was turned on, they would ejaculate "Isn't that fine !" or words to that effect, and were ready to proceed to the next exhibit. The point is that practically all of them looked at the exhibit from the doorway. Now, this way of studying a lighting installation would be entirely proper in the case of show window lighting, for example, for a show window is designed to be looked at, but an industrial shop is a place where work is to be done. It would have been entirely possible to make a presentable exhibit to be looked at in this way simply by having a bank of projectors over the doorway throwing light down into the room. Shadows would have been very largely hidden by the objects casting them, and the glare would have been directed away from the observer, but, of course, this would not have been good machine shop lighting. To get his exhibit across, the attendant in charge of this booth had to literally take people by the lapels of their coats and lead them into the room to show them the effects down on the work, as the workman would see and encounter them. They had to be made to look under the hood of the auto truck standing there, by the light of first a bare lamp on a drop cord and then of one of the general overhead systems; they were asked

to put themselves in the position of the workman looking, say, for a radiator leak. They were given a sheet of polished metal to manipulate in order that they might see the harmful effects of reflected glare. The effect of sharp deep shadows was pointed out at the work. This resulted in the visitor carrying away impressions much different from those obtained when standing in the doorway, but even then, I would venture to say, few of them mentally multiplied the discomfort and annoyance shown to them in a few minutes time by the number of times they take place in a full working day.

It seems to me that we have failed to emphasize in the past this "down here" phase of illumination. Ask the average man what he thinks of the lighting in a given room and the first thing he will do will be to look up toward the lighting units. The chances are that this is the only place he will look before rendering his verdict. Of course, it is entirely possible to reason from cause to effect and, knowing the characteristics of lighting units, to pass on the lighting that will result. But isn't this rather an indirect route ? We don't figure gear ratios when we want to know the speed at which an automobile is traveling. Rather, we estimate directly the speed at which the telephone posts are passing or else look at the speedometer. If reflected glare, sharp dense shadows, and lack of uniformity or proper intensity of illumination are as objectionable as the great number of pages written on them would indicate, certainly they must evidence themselves at the work. If direct glare, even, is as bad as we have said it is, it should hardly be necessary for us to hinge our necks backwards to detect it. I believe it is the fact that not enough attention has been directed to lighting effect on the work that is responsible for many of these factors being passed over as relatively unimportant by the laymen.

While we are discussing this matter of light from the standpoint of the man who is working by it, the question suggests itself as to how many of us have ever actually put on overalls and worked under lighting of different types over a period of time. By this I do not mean simply going into a shop and looking over a mechanic's shoulder while he is performing some task, but actually giving the thing a tryout over a period of time. I think we would find, for example, that even in classes of work that we

ordinarily do not consider exacting in their illumination requirements, there are a great many occasions where a high order of illumination would be of decided advantage to the workman, where bright specular images are particularly harmful, and where objects casting shadows which are black counterparts of themselves are confusing.

I know of a man, who admits that he should have known better, who gave considerable thought to the kind of lighting he would use over a workbench in his home and finally decided upon a good type of steel reflector to be mounted directly over the center of the bench. He even went so far as to take into account the distribution curve of this particular unit, and on the basis of point by point calculations applying the inverse square law he found that he could obtain a very satisfactory grade of uniform illumination on the workbench. He installed the unit. One of the first jobs that he did under this system was to lay off a board which he wanted to saw off accurately, and then to clamp this board vertically in his vise. Much to his surprise, when he came to apply the saw, he found that not only was the mark invisible, but that the entire surface was in shadow. No amount of painstaking calculation of one phase of the subject will compensate for ignoring plain horse-sense principles affecting other phases of it. If he had read carefully any of the many publications on the subject of lighting, he would have made provision for adequate illumination on vertical surfaces, and for the avoidance of dense shadows, at the time he put in his lighting, but those of us who have been publishing lighting information have had a way of making it so impersonal that it lacks something of a human force that makes it a real thing to be considered when lighting is installed.

The layman has not yet got to the point of applying even the most ordinary analysis to lighting. How often it happens when one is doing a piece of work and another person's shadow interferes that the worker looks up and says. "Please get out of my light" or the same thing in stronger or sarcastic language; or, "This material is very trying on the eyes—hard work to do at night." Under these circumstances the lighting arrangement is seldom if ever criticized.

We to whom lighting has long been a quantitative art do not always realize that the fact that light is measureable is in itself a new thought to most people. The timely development of a simple portable instrument, the footcandle meter, has already accomplished wonders in getting people to think of lighting in quantitative terms. Lack of uniformity of illumination, inadequate maintenance and insufficient intensity in general become obvious defects when lighting is subjected to simple tests that can be made by the foreman in the shop or a clerk in the office. Contrast the way we have had to present to the industrial man the subject of proper spacing and hanging height, for example, in the past with the way it can be done to-day. Formerly we were limited very largely to tables and charts, prosaic black ink on white paper, cold and lifeless. To-day the industrial executive himself can check up his intensities, and if Bill Jones has only half the intensity to work by as Tom Smith, doing the same kind of work, the matter is one not of mathematical niceties, but of fair play, and an opportunity, if need be, of bringing Jones' efficiency up to Smith's. To be sure, light intensity is only one factor in good illumination, but it is to be expected that consideration of this factor will automatically direct attention to others.

Experience has shown that the layman can readily be made to realize that what he wants in his lighting is foot-candles,—what if he does later refer to them as "foot-candle power," "foot power," or some other distorted name—so long as he knows what it is he wants in this respect. He readily grasps the idea that his lighting can be measured down at the work and that it can therefore be assigned a definite grade. What he does not always grasp, however, is the fact that these foot-candles must be safeguarded as regards glare, and other lighting defects. The quantitative side of illumination, broadly speaking, appears to be easily understood, but education in regard to the qualitative aspects of the subject calls for our best thought and effort, if we are to forestall disappointment on the part of the man who decides he will be his own illuminating engineer, but who possesses little knowledge beyond the fact that he wants a given number of foot-candles.

We hear considerable discussion at the present time as to what intensities are proper for different classes of work. Not many

years ago when light was much more costly than it now is, and when figures showing the benefits of good illumination were lacking, intensities much lower than those recommended to-day were considered at least passable. With the continuing decrease in relative cost of light, standards of intensity for properly installed lighting have been rising from year to year, showing that the value of higher standards of illumination was appreciated but that the bugbear of cost was until recently without compensating advantages that could be definitely evaluated. Obviously, there is a limit or limiting region of intensities beyond which increased illumination will not be accompanied by these advantages—at least, not to the extent of being justifiable from the standpoint of cost. Since we have yet to hear of data presented to show that this limit has been reached, we may assume perhaps that it lies somewhere beyond even the highest standards of present-day practice.

If lighting had always been installed properly, intensities would by now have had a chance to find, approximately at least, their own proper level. As it has been in the vast majority of cases, when a need for more light was felt and steps were taken to get it, glare gave rise to the verdict "too much light." When the carbon filament incandescent lamp first became available commercially, it was pointed out that in using it to replace gas for lighting, the wires could be run through the gas pipes already installed and the new lamp substituted for the gas burner. That, in a nut-shell, has been the history of average lighting practice—the mere substitution of a new light source in the place of its predecessor, with little or no modification of equipment. The substituting of a carbon filament lamp for a gas or kerosene burner was not extremely bad; substituting a tantalum or a Mazda B lamp for a properly used carbon lamp would not have been so terrible; if the Mazda B lamps had been carefully installed, and later Mazda C lamps had been substituted, the situation, while not good, would not have been calamitous. But Mazda C lamps installed in accordance with coal-oil practice are a positive and definite hindrance to this remarkable product of science and engineering in accomplishing its maximum usefulness. So rapid has been the development of the incandescent lamp itself that a condition approaching the one just mentioned is very general indeed. Proper application of the lamp has not

kept pace with progress in development of the lamp, and to-day, instead of constructive, preventive effort leading and pointing the way, corrective effort is scrambling to catch up. To-day, when we specify, say, a ten foot-candle system that is right as regards direction, distribution and diffusion of light, we not only correct the misuse of light in these respects but make up in part at least for time lost because of retarded evolution toward proper intensities in the past.

It is unnecessary to state that the man who sells lighting, whether his particular immediate commodity is kilowatt-hours, lamps, or reflectors, is awake to the sales opportunities afforded by the new appreciation of lighting, and is showing a decided tendency to direct his salesmanship toward selling, instead of these specific commodities, foot-candles properly supplied. Salesmanship is doing as much as any other force to spread the advantages to all concerned of modern lighting, and it will succeed in this respect only in so far as it sells that which is of lasting good for the buyer. It has been pointed out repeatedly to commercial groups that glare instead of being a purely technical subject is a vital commercial one, a brake on progress which makes it impossible for them to increase their sales by advocating higher standards of illumination; and if these people appreciate the significance of this statement, as I believe they do, they will be energetic anti-glare missionaries. On the other hand, if they sell high intensities to the exclusion of proper diffusion, they will find that these installations will be short-lived, and it will be only a matter of time before the installations will drop back to their old levels of illumination. Also, if other requirements of good illumination are not met, the customer will not be fully satisfied with the resulting system. The salesman is a force for good or ill and if his efforts are directed in proper channels he is the man on the firing line who can do more toward furthering the cause of lighting from state to state, city to city, and shop to shop than any other single agency.

Incidentally, this word "intensity," especially when used in the phrase "high intensity" as descriptive of a class of lighting, while proper from the standpoint of engineering nomenclature, is an unfortunate one from other standpoints, for it suggests an intensification of what the average man has considered good lighting,

including naturally an intensification of the things that have been annoying to him in the past. It further carries an idea of tenseness, forced production, and straining to the limit, which is entirely erroneous and which could be avoided by a more appropriate descriptive phrase generally agreed upon.

There is, as has been said, a new interest in lighting on the part of people who use it, but a lack of proper appreciation of what good lighting is and of the factors that enter into it. One reason for this is undoubtedly to be found in the way we have couched our message to these people, in fact, when we analyze material that has been published on illuminating engineering, we find that we have been talking to each other rather than to the man who uses light. This literature, while it makes great reading for the man trained to assimilate technical matter, lacks something of the element of human experience necessary to make it interesting to other men of affairs who as yet do not know that they have a vital interest in all phases of the subject. What literature has been written directly to the user of light has so often in the past been sprinkled with commercial superlatives to an extent to cause it to be discounted. We enjoy reading that which, whether fiction or philosophy, strikes a responsive note in our own being, that causes us to put ourselves in the shoes of the hero of fiction or to compare with our own the theories of the philosopher. Herein lies the answer as to why many articles which are interesting to you and to me have no appeal to the man really in need of the information. The mere mention of barked shin-bones starts a train of thought in the average reader's mind much more effectively than a statement to the effect that improper illumination of aisleways is liable to result in injury that will entail loss of time and perhaps permanent disability. Everybody has at some time had this experience, and knows without you telling him that it hurts; he knows too that what he was doing at the time became of importance very much secondary to nursing the aching member and that an appreciable loss of time as well as temper resulted. By illuding to it we put our finger tip on a sensitive memory spot more powerful to start a train of thought than a 20-mule team. This is equally true of less unpleasant recollections. We go to a ball game and after an uphill struggle abounding in thrills, the home team wins out in the ninth inning. The next morning we

read the account of the game in greater detail than if we hadn't been there to see it. When the afternoon paper comes, we are eager to read another editor's version of it, and again go through it all play by play. This theory is in itself an old one, practiced for years by newspaper writers, and, if mention of it here is of interest, proves its own truth. If the message of illuminating engineering is to be carried forcefully to those beyond the circle of men making their living in lighting, we have got to feel for these responsive chords in the minds of people we are talking to, and reduce matters of spacing, glare, diffusion and so on, into living terms, remembering that at all times we have got to overcome a feeling on the part of the average man that he knows about all there is to know about using light, since it is an art that dates back as far as history itself; he does not realize that compared with advances in the past fifty years, this art was at a standstill during the previous fifty centuries, and that the use of artificial illuminants is a vastly more serious problem to-day than when our grandmothers were young.

By way of concluding these very general and more or less random remarks, which are in a way introductory to a discussion of photographs in albums about to be distributed illustrating industrial lighting of the new order, I will repeat that there is on the sidelines a growing appreciation of what illuminating engineering makes possible. It is being recognized that lighting gives to the industries the equivalent of some new type of automatic machinery; that it is a potential force for giving to society every year human lives which would otherwise be lost, of greatly decreasing the number of people maimed, and of contributing in numberless ways to the fullness of living. The new appreciation of lighting does not apply to the industries alone, for it is no less evident in the various commercial fields. In the street, life, limb and property are safer when good illumination is provided, to say nothing of stimulated sociability, commercial activity and civic pride. The vast field of lighting typified by the American home is, perhaps, the slowest to avail itself of what illuminating has to offer, but even in this field there are signs of growing recognition of what lighting can do. So far-reaching are the effects of good lighting that the illuminating engineer perhaps fails to appreciate the tremendous social and economic force that he wields.

360$\frac{9}{}$

Before.

After.

What Illuminating Engineering is doing for industry.

DISCUSSION.

Mr. Burton: One lighting fixture manufacturer, the company whom I am connected with, is endeavoring to further the sale intelligently by the jobber's salesmen of all types of lighting appliances. It is being earnestly recommended that all electrical jobbing firms selling various lighting equipment, place in direct charge of these sales, a competent illuminating engineer who should be working very closely with their lamp salesman. Such a man preferably should have had considerable experience in the lighting industry with knowledge of such installations as: show window and show case lighting; lighting of offices; drafting rooms, residences; industrial installations, both general and localized lights; use of flood lighting projectors for illuminating sign boards, building fronts, monuments, and for protection purposes. If such lighting departments could be established by the jobbers, it would be a long step ahead. It is hoped that within a year, lighting departments will have been organized by many of the larger electrical jobbing houses throughout the country.

Mr. Anderson: At the present time while other costs in manufacturing, such as labor, and practically all materials, are increasing, light costs only 10 per cent. of what it did in 1909. Stating this in another way, if one foot-candle of illumination paid for itself 10 years ago, the manufacturer can now afford to have 10 foot-candles, even if no additional benefit in production results. Actually the increased illumination can be counted upon to result in better production and fewer accidents.

In considering the cost of an artificial lighting system, it should be kept in mind that daylight illumination in interiors is not without cost. It is, of course, the duty of every illuminating engineer to take as much advantage of daylight as possible, but, I believe it has been the experience of everyone who has gone into the subject, whether in designing an office building, shop, art museum, or other building, that the provision of adequate daylight often means a considerable sacrifice in space and increase in cost. There are only certain distances to which a fair amount of daylight illumination may be expected to reach in a room of given ceiling height, and correspondingly, the width of the build-

ing is limited if daylight is to be depended upon throughout. In some cases it is an economic advantage to use the wider building and to calculate on using artificial lighting in a part. There are, of course, a number of industrial plant rooms where during 24 hours of the day no reliance whatever is placed on daylight.

There seem to be more and more applications of the straight general lighting system in replacement of the old local or combination of local and general lighting. With available lamps and equipment it is practical to design a general artificial lighting system to give the same results in interiors as daylight. In general any job that is satisfactorily done by daylight can be done by the proper design of general lighting. There are some places, of course, where local lighting is needed. For instance, a standard overhead general lighting system will not deliver much light inside a pipe, open only at the bottom, but it is also true that daylight cannot be depended upon for this job.

Referring to the question of intensity, it seems that in many cases it is thought that the color or direction of the light is wrong, when as a matter of fact the provision of an additional amount of light by cleaning the old lighting units or by changing to sources giving a greater illumination would solve the problem.

MR. COLVILLE: The need for more extensive educational work has been pointed out. I believe we should be encouraged by the hope that as the interest in lighting increases, people are going to get the information they require. When a man buys a camera for the first time, or buys an automobile for the first time, he becomes very much interested in details which before were absolutely blank to him; he eagerly seeks all the information available, and studies it carefully; and as the results of good lighting become more widely known than they are at present, we shall see, I think, an interest on the part of the consumer which will result in his getting the information he needs.

THE DEVELOPMENT OF ELECTRIC SIGN LIGHTING.*

BY E. A. MILLS.

In tracing the development or improvement in electric sign lighting, referring specifically to illumination rather than to advertising, it may be said that these developments or improvements followed along very generally with the improvement of the incandescent lamp. It is only right at this time to say also that the various improvements can be directly traced to the educational work of the Illuminating Engineering Society towards scientific lighting.

The development of electric signs and lighting has followed along two general lines—improvement in lamps, and improvement in design and construction.

Considering first the question of lamps: at the outset, of course, there were no specially designed sign lamps. When, however, the carbon filament lamp had reached the stage that it could be produced in sizes other than the standard 16 cp. size, the electric sign suggested itself as a commercial possibility. As time went on the 4 cp. carbon lamp came to be recognized as a standard lamp for sign work. Its excessive current consumption at the then rather high rate per kilowatt hour militated against the widespread use of electric signs.

To the low watt standard voltage tungsten filament lamp may be given credit for enormously increasing the use of electric signs. The wonderful flashing and spectacular effects now so common could hardly be accomplished with the carbon filament lamp owing to its inherent sluggishness in attaining its full light intensity, as well as the slow fading out effect when the current is turned off. The tungsten filament lamp has been a boon to this class of work.

The tungsten filament lamp when first produced was made with a squirted filament and was naturally very delicate. It was also impossible to make it in standard voltage. As first constructed, it was made up for about 10 volts, and for direct current work it was necessary to connect 12 lamps in series. For alternating

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current work transformers could be used. The series connection is particularly unsuited for sign work as the failure of one lamp extinguishes the group with consequent disaster to the legibility of the sign.

Later on the multiple series connection was tried. This was an improvement on the series, but was restricted in use to signs containing 100 lamps or more. Such connections except for off-and-on work did not lend themselves for flashing.

The advent of the drawn filament 10 watt standard voltage sign lamp solved these difficulties and it may be considered the standard lamp at this time.

Coincident with the improvement in lamps came about a corresponding improvement in sign construction and design. To understand these properly a little historical discussion may not be amiss.

Consider first the illuminated signs that immediately preceded the electric signs. These, of course, were illuminated by gas. As a rule they were of box construction with the gas jets inside. The sides of the box were usually studded with vari-colored glass jewels outlining the letters. These signs were usually found outside of drug stores, oyster houses, etc.

There was another type of gas illuminated sign which could be used only indoors as it was readily extinguished by every slight breeze. This sign was made up of brass or copper tubing bent in the shape of letters, and drilled at regular intervals and the gas pressure so regulated that only a tiny flame was emitted. The result was very striking even though the sign was more or less of a fire risk.

The first electric sign that we have any record of, and surely the first we have any photographic record of, came shortly after the commercial use of the incandescent lamp was demonstrated. This sign, constructed by Major W. J. Hammer, very appropriately spelled out the word "Edison" and was used at the International Exhibition in the Crystal Palace at London in 1882. The records seem to show that this sign was flashed on and off by means of a large hand operated commutator and a spring lever switch.

The second sign also constructed by Major Hammer likewise read "Edison" and was shown at the Edison pavilion in the Health Exhibition at Berlin in 1883. This sign was flashed on

letter by letter through means of a commutator driven by an electric motor.

It was some time after this before the electric sign suggested itself for commercial use and the first one of this class that we have record of, was used in a field still popular to-day, namely the theatre. This sign was installed in 1894 in front of Miner's Fifth Avenue Theatre, 28th St. and Broadway, and read "Miner's Fifth Avenue Theatre—Fanny Davenport."

The first large display sign was placed in 1896 on the north wall of the building facing Madison Square on the side now occupied by the Flatiron building. This sign advertised Manhattan Beach "Swept by ocean breezes," "Gilmore's Band," "Brocks' Fireworks."

Later on Admiral cigarettes and Heinz' Pickles were advertised here. This sign may be considered the father of the present Broadway display signs, and was erected and operated by the O. J. Gude Company. This sign contained colored lamps and was flashed on, one line at a time, then all out, then all on. This was accomplished by hand switches operated by an attendant located in a small shanty on an adjoining roof.

These pioneer signs were naturally of crude construction. There were no specially designed sign receptacles and the Fifth Avenue Theatre signs already mentioned consisted of wooden letters through which holes were bored for the insertion of regular wiring receptacles. The wiring was all open on the backs of the letters which in turn were bolted to a wooden framework. Since then special waterproof sign receptacles have been developed. In the early stages these were inserted through punchings in the face of the sign and held in place by small brass machine screws. This type has since been superseded by a receptacle which is either self-locking in the face of the sign or held in place by porcelain bushings screwed through from the front.

Flush Letter.—The original signs were made up in what is known as the flush letter (Fig. 1), that is, the letter was painted on the background and the receptacles mounted therein. This type of construction has many faults—in the first place the sign is difficult to read at an angle. All that is usually seen is a mass of bulbs; furthermore, the lamps illuminate the background as

well as the letters, resulting in considerable halation and consequent illegibility.

Block Letter.—To overcome these objections the raised block letter was developed (Fig. 2). In this type the letter is raised from the surface of the background. While the results obtained are a great improvement over the flush type, there is still considerable halation.

Groove Letter.—To overcome these objections, the groove letter, sunk below the background, was developed (Fig. 3). In this type halation is absent, the light from the lamps is confined to the groove and the background remains in total darkness, giving wonderful definition and legibility at night, particularly when viewed from in front. This type of letter, however, had the fault of being costly to construct, was rather indistinct when viewed from an angle. Likewise the placing of the receptables below the surface of the background made the sign rather bulky or thick, particularly in a double-faced sign.

Wall Type Letter.—The latest development and the type of letter generally used now is known as the wall type (Fig. 4). Such a letter is virtually of the flush type but the letters are outlined by a wall of metal of sufficient height to confine the light to the enclosure and prevent it from spilling over the adjacent letters and the background. The usual practice is to paint the channel a flat white and to improve its daylight legibility, the edge of the wall is turned over and painted a color contrasting with the background. To improve the reading at an angle by daylight, the outside wall is also painted a color contrasting with the background. This type of letter can be as cheaply constructed as the flush type, is characterized by absence of halation as in the groove type, and is an improvement over the latter on this when viewed from an angle. It may now be regarded as a standard type of construction.

Roof Signs.—So far this discussion has been confined to the general type of letter employed in signs used directly over the sidewalk or on the face of buildings. The roof or sky sign also presents its difficulties and under certain conditions has to be handled in a different manner. The usual custom is to paint the face of the letter a flat white, and with a contrasting background,

this is good practice (Fig. 5). Where, however, the letter is of the so-called skeleton type and the sky is the background, a white letter would be nearly invisible by day and in such instances the letters are painted black, an example of this being the Colgate sign in Jersey City.

A somewhat similar sign though lighted in an entirely different manner was designed by the author and is located on the roof of the Bronx office of the New York Edison Company (Fig. 6). In this sign the lamps are not exposed to view. The face of the letter is slightly smaller than the surrounding wall leaving a small space or outline through which the light is emitted. This type of construction gives a very striking effect and is believed to be the only sign of its kind ever constructed.

Where a large roof sky sign is to be read at a considerable distance a different method of treatment is necessary. In order that the sign may be read by day the stroke of the letter should be made wide. This however, is a decided drawback from the standpoint of legibility when lighted, particularly where the letters are close together as the halation is more pronounced as the distance increases. To overcome this the letter is divided by walls in which the lamps are located. This gives much better spacing between the letters and makes for better legibility by night without interfering with the daylight appearance.

Panel Sign.—So far we have considered only the so-called lettered sign. These naturally from their make-up are costly to operate containing as they do such a multiplicity of lamps. To give the small consumer an opportunity to use electric signs various adaptations of the electric sign have been evolved.

The panel sign consists of a frame containing 24 lamps (12 on each side) surrounding a central panel on which the advertisement or announcement is painted (Fig. 7). This sign has the advantage of cheapness and lends itself to ready change in wording should the place of business change hands, but it has, however, the defect of excessive halation—in some cases the announcement is almost obliterated.

Panel Reflector Sign.—To overcome the above objection and at the same time retain the interchangeable features, the author designed the panel reflector sign. Here the lights are hidden from view and the result is very pleasing.

Bulls-Eye Sign.—For those who desire a sign approaching the lamp letter in general appearance but avoided its multiplicity of lamps the so-called lens of bulls-eye type has been devised (Fig. 9). This produces a fairly good daylight sign but at night is rather spotty particularly when spectacular attempts are made.

Flexume Sign.—The flexume or oplux is a very pleasing and effective type having all the advantages of the lens type as far as economy of operation is concerned, and presents a satisfactory appearance both by day and night (Fig. 10). In this type the background consists of a stencil. The lettered spaces are filled with convex opal glass. This produces a sign very easily read at an angle and particularly clear both by day and night.

Cut-out Sign.—Still another type is the so-called cut-out sign (Fig. 11). The letters are located inside the sign body and the letters are outlined by holes punched along the edge of the letter in the stroke itself.

Transparency.—A later and now popular type is the so-called glass panel transparency (Fig. 12). This combines all the features of economy of operation incident to the foregoing types with the added advantage of getting away from the rather fixed or stereotyped signs. In the transparency considerable lettering may be used to good effect in a small space. The artist may run riot as to coloring and design. The sign is entirely free of halation and the effects produced are altogether pleasing both by day and night. To avoid bright spots the back is painted a heavy white.

Suggestion Sign.—New York City, as is well known, is made up of all kinds of people. There are many to whom a sign is nothing more than a sign. To be effective the sign must also visually suggest something. Thus a shoe store sign is made in the form of a shoe, etc. (Fig. 13).

The electric sign has been considered above from a more or less general viewpoint. A sign to be serviceable should be clear by day and particularly at night. This has been accomplished by adopting the wall type letter confining the light to the space to be illuminated and using bowl frosted lamps to reduce halation. Ten watt 120-volt Mazda lamps are generally used; although in some large display signs 5-watt, 60-volt lamps are employed. The

legibility of many signs would be improved by the use of low wattage lamps could they be manufactured to stand the hard usage received by sign lamps. Natural colored glass lamps are rarely used owing to their high cost. Instead, colored effects are produced by placing color-glass caps or hoods over plain lamps. This makes for economy as the color cup may be used repeatedly. The cap which only covers the bowl of the lamp acts as a reflector by throwing the light on the letter thus further enlivening the effect.

Spectacular and moving effects are produced by medium of rotating commutators or flashers operated by motors. The different effects produced naturally vary with the type of flasher used and the method of wiring.

What the future developments will be, is hard to say. More recent developments are improvement in bill board illumination with the advent of the nitrogen lamp together with the improved type of fixed reflector located at the top of the board and out from the surface; changeable color effects have recently been used in connection with billboard displays; a tendency to combine billboard displays with true electric sign letters; the use of the nitrogen lamp has exceptional brilliancy, except under special conditions of sign construction, and distance from the point of view, together with excessive breakage, is apt to prevent the use of gas filled lamps for sign work to any great extent. Another recent development in lighting effects is produced by placing the lamp behind an opaque object which is raised from the background, thereby giving the object greater contrast. Fixed reflectors are used for general illumination, and the hidden lamp to accomplish the contrast referred to. An example of this type of sign advertises Lucky Strike Cigarettes at 42nd Street and Broadway.

A very effective painted sign on a blank wall advertises Kelly's Springfield Tires, on Broadway and 59th Street, and their well known trade-mark is brought out in great contrast to the sign proper by focusing a flood light unit on the trade-mark.

Another type of sign is located on the sidewalk before the New Amsterdam Theatre, calling attention to the current attraction. The sidewalk referred to, consists of the usual vault lights,

beneath which is placed the electric letters, the light from which shines through the bull's eyes. This type of sign naturally is very circumscribed in its use, owing to the very special sidewalk construction necessary.

The tendency seems to be along the lines of producing artistic designs and spectacular effects so far as lamp letter signs are concerned. The improvement in billboard design and construction, as well as lighting has been very marked during recent years, and the indications are that this type of display will be further improved as time goes on.

DISCUSSION.

Chairman: This has been a very interesting paper and I am sure there will be a great deal of discussion upon it. As there is another paper to follow, I shall have to ask you to confine the discussion to three minutes each. We have in the room two or three gentlemen that I know have done some interesting pioneering in sign work. I will ask Major William J. Hammer to tell us of his early work on signs.

Major Hammer: I believe the first electric sign ever invented which employed the incandescent electric lamp was designed by myself early in 1880, while I was an assistant of Mr. Edison at his laboratory at Menlo Park, N. J. I still have the original drawing of this sign in my possession. It was designed to operate by a clock switch which flashed on and off two Edison paper horseshoe carbon filament lamps, which were enclosed in a small sign with a ground glass front plate with the name Edison painted thereon. The first two signs shown upon the screen by Mr. Mills in his admirable paper may be truly said to have founded the art of electric sign lighting, which has grown to such enormous proportions. I have brought with me this evening some excellent photographs, showing details of these signs and in the brief time alloted to me, I shall be glad to say a few words regarding them.

The first sign (Fig. 1) was erected over the large organ in the Concert Hall at the Crystal Palace Electric Exhibition in February, 1882, at which time I held the post of chief engineer of the English Edison Electric Light Co. This sign was about 10 ft. in

370'

Fig. 1a.

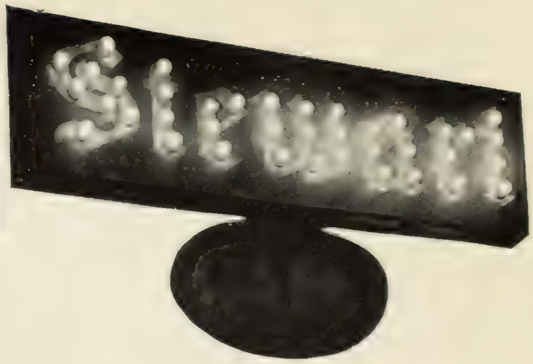


Fig. 1b.

Flush letter

Fig. 2.—Block letter

Fig. 3a.

Fig. 3b.

Groove Letter

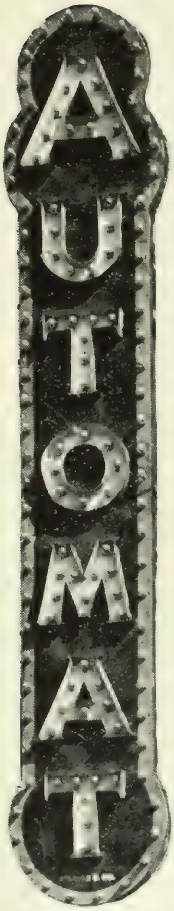


Fig. 4a.

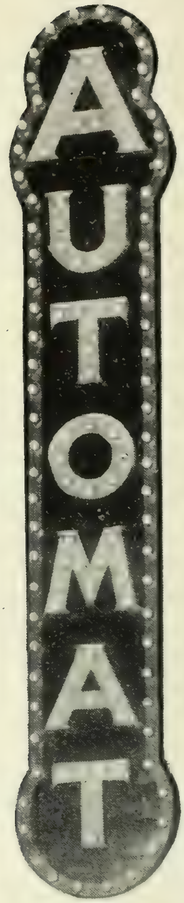


Fig. 4b.

Wall Type letter

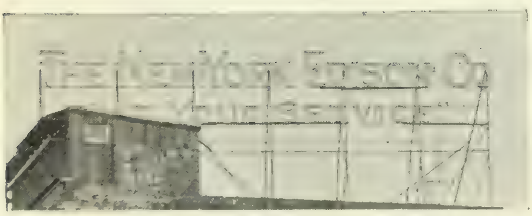


Fig. 5a.

Fig. 5b.

Roof Sign

Fig. 6.—Roof Sign

Fig. 7.—Panel Sign

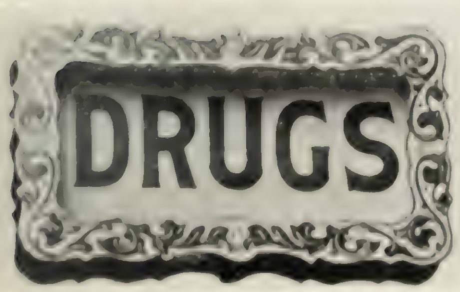


Fig. 8a

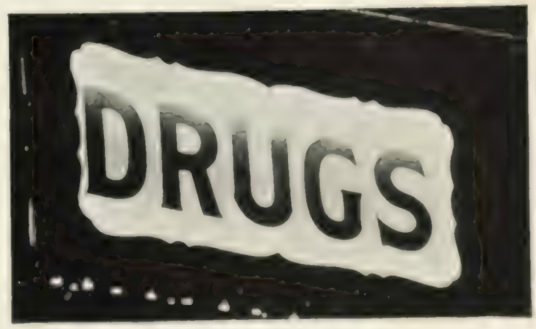
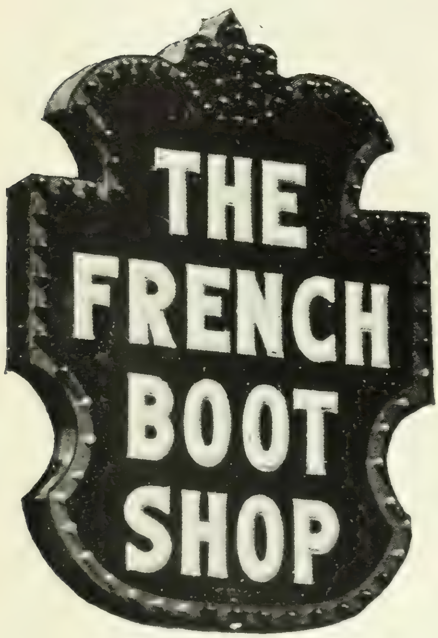


Fig. 8b

Panel Reflector Sign

Fig. 9a. Fig. 9b.

Bulls Eye Sign



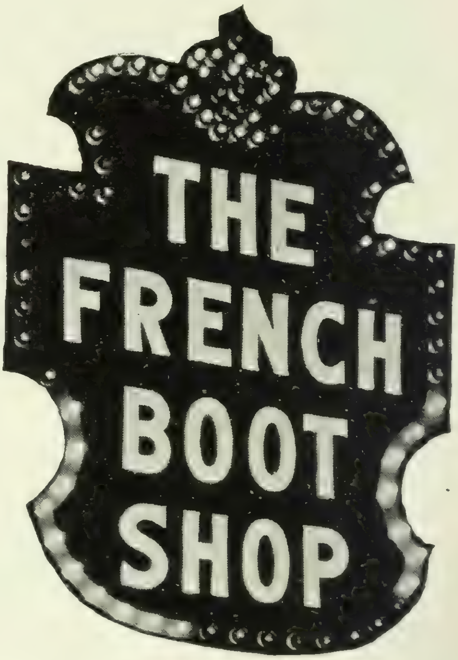


Fig. 10a. Fig. 10b.

Flexume Sign

Fig. 12a. Fig. 12b.

Transparency

Fig. 11a.

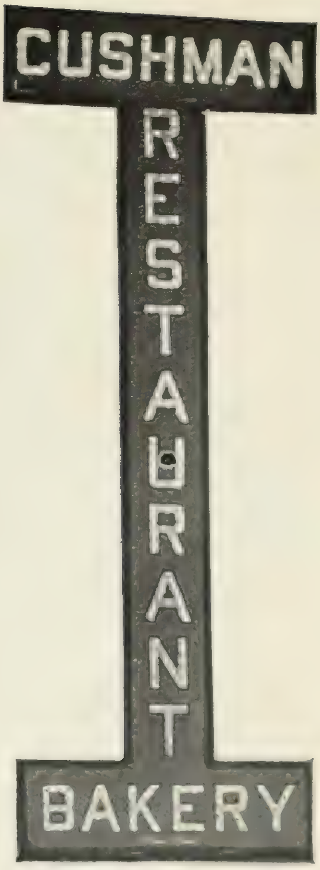


Fig. 11b.

Cut out Sign

Fig. 12a.

Fig. 12b.

Suggestion Sign

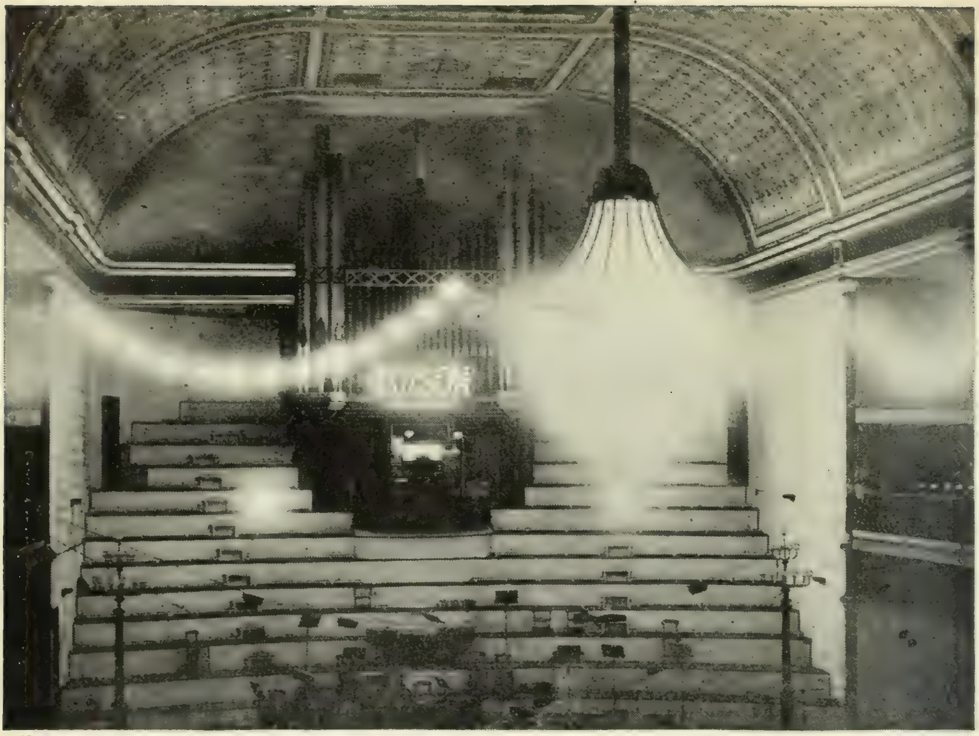


Fig. 1.—The First Electric Sign ever made. It was placed in the Concert Hall at the Crystal Palace Electrical Exhibition, London, England in February 1882.

Fig. 2.—The First Motor driven "Flasher" sign ever made. It was placed on the Edison Pavilion at the Health Exhibition in Berlin, Germany in 1883.

length and spelled the name Edison in letters about 1 ft. high and averaging about a dozen 16 candle-power Edison carbon filament lamps to the letter. The lamps were mounted in wooden sockets into each of which were screwed the head of a double ended screw, which at the top was threaded and carried a deep slot to permit the wires to pass into the sockets. The lower end screwed into the baseboard of the sign. The sign was operated letter by letter and as a whole by means of a hand operated commutator, and a huge lever spring switch and was in operation during the entire exposition.

The second sign (Fig. 2) I built in Berlin, Germany, in 1883 at which time I held the post of chief engineer of the German Edison Co., and this sign which embodies the basic principles of all motor driven flashing signs of to-day, was erected on top of the Edison pavilion at the Health Exhibition held in Berlin in 1883. The sign as illustrated was of arched form and like its predecessor carried the name "Edison" in 2 ft. letters employing 87 16-candle-power Edison carbon lamps. The lamps were mounted in socket receptacles, fastened to the baseboard, a perforated sheet metal face plate was attached to the front of the sign, the lamps protruding through the openings in the plate and each lamp was provided with a special rubber gasket to keep the rain and snow out of the socket. An electric motor driven flasher geared down in speed flashed the letters one after the other and then the sign as a whole was operated precisely as are the modern motor driven flashing signs. This device operated during the entire exhibition without failure. I regret that there is not time this evening to go into other automatic signs and many devices, such as waving flags, etc., which I made in the early days. Perhaps I can do this at another time.

DAYLIGHT SAVING.*

(Abstract.)

BY PRESTON S. MILLAR.

This paper deals with the advantages and disadvantages of "Daylight Saving" as experienced in the part of the United States lying north of the Potomac and Ohio Rivers and east of the Mississippi River. Statistics of outputs of electric and gas central stations are shown, indicating for different stations comparisons of total output and of hourly output on comparable days under daylight saving and under standard time. The general indications of reduction in output due to daylight saving are as follows:

Reduced electricity output, total systems, during seven summer months	3 per cent.
Ditto—residential loads only	8 per cent.
Ditto—gas station, total output	3 per cent.

Estimates of the approximate savings in coal and in expenditure for light throughout the entire country during seven summer months under daylight saving are as follows. These of course are only approximate, being subject to very considerable error.

	Annual saving in coal	Annual saving in expenditure for artificial light
Electricity (central stations)	300,000 tons	$14,000,000
Gas	195,000 tons	5,250,000
Totals	495,000 tons	$19,250,000

The paper traces the history of the daylight saving movement abroad and in this country and then proceeds to sum up the results of the author's inquiries into the advantages and disadvantages of daylight saving. The advantages are shown to include more outdoor recreation for those who are in a position to avail themselves of the opportunities afforded by the additional evening hour of daylight, and saving in fuel and in expenditure for artificial light as shown above.

* Abstract of paper presented before the Philadelphia Section, April 16, 1920. Full paper may be found in the Journal of the American Institute of Electrical Engineers, February, 1920.

Advantages which have been alleged but which do not appear to be clearly proven are: increase in gardening where daylight saving assists the amateur gardener but impedes the professional gardener and benefits conferred upon the health of the public where the advantages of increased outdoor recreation for a part of the public appear to be more or less offset by the disadvantages of earlier retiring and rising in the case of the urban poor.

Disadvantages which have been clearly demonstrated are those under which farmers, dairymen, miners and perhaps other outdoor workers labor due to being compelled to start work one hour earlier in the morning or to lose time by reason of the fact that others quit work one hour earlier in the evening.

The author's deductions and opinions are in general that the 24 hours of the day have been distributed among work, recreation and sleep as a matter of evolution in which the comfort and convenience of the greatest number of people have been the only desideratum. In advancing activities during the summer by one hour, the well-to-do articulate part of suburban and urban communities is advantaged while the poor in urban communities and most of those in rural communities suffer disadvantages. It would seem more important to serve the interests of the latter and departure from standard time in the direction of daylight saving seems therefore inexpedient. Diversification of hours of industry serving the convenience of different classes of people seems more desirable than misadjusting the time in order to impose the wishes of one class of the population upon all.

THE RLM STANDARD REFLECTOR FOR INDUSTRIAL LIGHTING.*

WARD HARRISON.

The permanence of a porcelain enameled steel surface, even under unfavorable atmospheric conditions, its moderate cost, and the ease with which it can be kept clean have made it the most generally employed among all industrial reflector surfaces. Up to the present there have been numerous types of porcelain-enameled steel reflectors of various degrees of merit commonly employed; those in the most general use being the flat cone, deep bowl, and shallow dome.

The flat cone is really never to be recommended for the illumination of interiors, since a higher intensity of illumination of better quality can be obtained with other types. With the flat cone the edge of the reflector is at or above the center of the lamp filament; hence, not more than one-half of the light is intercepted and the efficiency of the unit in directing light to the work is of necessity low. Much of the light is emitted at or near the horizontal, and, striking high on the walls of the room, is to a large extent wasted. No shielding of the bright filament of the lamp is afforded; hence, the glare is pronounced except where the units are used in very high bays, and there the waste of light is very great. Where lamps are suspended low, even those with frosted bulbs are glaring. That proportion of the total light which is received from the reflector is insufficient to soften shadows appreciably.

As an emergency measure only, for the betterment of existing installations of flat reflectors, the use of a glare-shield supported either on the lamp bulb itself or by a holder extending from the reflector or socket is sometimes employed. The inner surface of this shield is made to act as a reflector, in which case the light is largely emitted from this small surface and the lamp itself. Only a small percentage is contributed by the large upper reflector; hence, shadows are sharp under such illumination.

The deep or bowl-reflector has been largely employed to give maximum shielding of the lamp filament. The output of typical bowl reflectors is not more than 65 per cent. The candlepower

* Paper presented before the Philadelphia Section of the Illuminating Engineering Society at Washington, D. C., March 19, 1920.

below the unit is at no angle materially greater than for the dome because of the losses resulting from cross reflection in the reflector; and at the higher angles the intensity is considerably reduced. Surfaces above the general level of the work are frequently inadequately lighted with such units and a room with dark walls is likely to appear dingy. While the deep reflector does shield the eye from the direct glare of the filament, it does not in any way modify the brightness of the filament images reflected from polished surfaces. Furthermore, the surface from which the light is received is so small that shadows are sharp and may prove annoying.

Porcelain-Enameled
Flat Cone, Shielding Band

Clear Lamp

Zone	Lumens	% Total Clear Lamp
0°-60°	1490	51
0°-90°	1900	65
90°-180°	29	1
0°-180°	1930	66

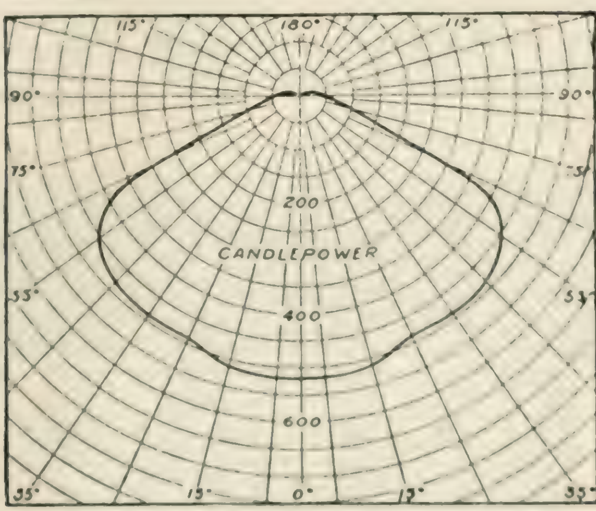


Fig. 1.—Flat cone reflector with glare shield.

The dome shape, a mean between the flat and bowl types, became the standard for the majority of installations of Mazda B lamps and steel reflectors. The output of typical reflectors is 75 to 80 per cent. of the light generated by the lamp; the percentage of light utilization is as high as with any enameled steel unit. The large area of the reflector provides a source of illumination which tends to minimize the harshness of shadows. Experience shows that under most conditions the eye is sufficiently shielded

from glare when Mazda B lamps are employed, yet enough light is emitted at the higher angles to illuminate higher vertical and oblique surfaces properly. However, with Mazda C lamps in these reflectors, the greater brightness of the filament makes the protection from glare insufficient.

While most of the porcelain enameled reflectors for industrial lighting until recently fell within one of the above mentioned general classes, there were almost as many individual designs on the market as manufacturers. Practically all were originally intended for use with vacuum lamps and did not utilize the output of the newer and more efficient light sources to the best advantage. The Mazda C lamp, with its concentrated filament, has made it possible to achieve a more nearly ideal reflector design than was possible with the Mazda B lamp. In order to establish high standards for reflectors used with these lamps and to assist in simplifying the selection of proper reflecting equipment the principal manufacturers of metal reflectors and the illuminating engineers of the Mazda lamp manufacturers, after a thorough study of the requirements have evolved a standard design which virtually combines the advantages of the older dome and bowl types.

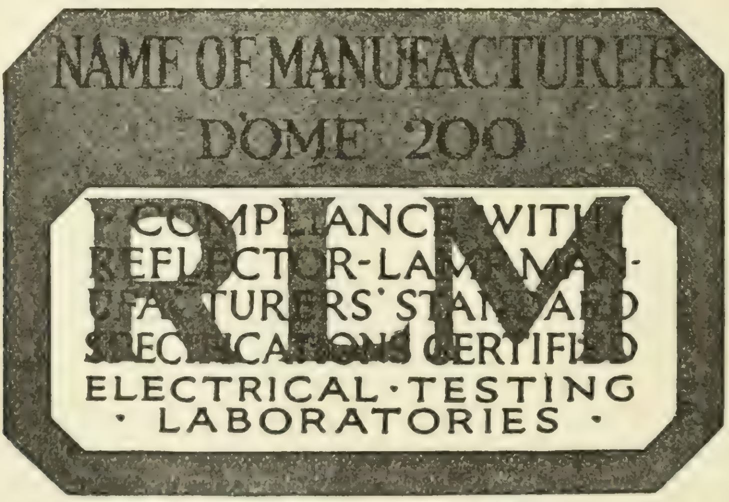


Fig. 2.—Certificate of inspection service.

The specifications for this design have been issued by the Research Laboratory of the General Electric Company, and are known as Reflector and Lamp Manufacturers' (abbreviated RLM Standard) specifications. They provide (a) a durable and highly

efficient reflecting surface, (b) a contour of reflector which will insure an effective light distribution; (c) a depth which will cut the filament center off from view at an angle of 72½° from the vertical axis thus sufficiently screening the light source to minimize glare.

Reflectors which comply with these specifications bear a statement to that effect in the form of a certificate of Inspection Service over the signature of the Electrical Testing Laboratories of New York City, who have been retained to conduct such periodic inspections and tests as will insure the uniform maintenance of the high quality prescribed in the specifications. The certificate, Figure 2, includes the standard designation for the reflector to which it is affixed; *viz.*, RLM Standard Dome-100, RLM Standard Dome-200, etc., depending upon the size of lamp with which the reflector is to be used. The certificate of Inspection Service gives assurance of a high standard of quality and performance for the reflectors on which it is found. The service is open to all manufacturers of metal reflectors without discrimination and those products which bear the Electrical Testing Laboratories' label are approved by the Research Laboratory for use with corresponding sizes of all Mazda C lamps manufactured in the United States. Only reflectors bearing the Electrical Testing Laboratories' certificate of Inspection Service may be advertised as complying with the RLM Standard Specifications.

The light output of enameled steel reflectors is dependent upon the quality of the porcelain enamel surface. On ordinary inspection, the porcelain surfaces of two reflectors may appear no different in quality, but the results of photometric tests may show a difference of 10 to 20 per cent. in their reflection factors. It is, of course, impractical for the reflector manufacturers to check their products by obtaining distribution curves for each lot of reflectors which they manufacture on account of the time and expense involved. The photometer shown in Figure 4 has been developed to fill the need for a simple device which with one reading will give an indication of the reflection factor of porcelain-enameled steel surfaces of a given contour. After the photometer has been calibrated the output of a reflector may be determined at one reading.

The complete specifications are as follows:

REFLECTOR AND LAMP MANUFACTURERS' STANDARD SPECIFICATIONS

For Porcelain Enameled Steel Reflectors

The Reflector and Lamp Manufacturers' Standard (abbrev. RLM Standard) specifications for dome reflectors, are as follows:

DOME REFLECTORS

Art. 1. Material and Workmanship—The material shall be porcelain-enameled steel. The quality and weight of material, and the workmanship, shall be such as to insure a good serviceable product, which will withstand ordinary handling without losing shape and without cracking of enamel.

Art. 2. Angle of Cut-Off—In every case the reflector shall present a continuous surface so proportioned that in ordinary use with a corresponding MAZDA C lamp of present standard light center length (see table in Article 3), the filament center will be cut off from view at an angle of 72½ degrees from the vertical axis (17½ degrees below the horizontal). The mean angle of cut-off for a group of reflectors shall not depart from the specifications by more than 1½ degrees, nor individual samples by more than 2½ degrees.

Where reflectors having 2¼-inch fitters are supplied without holders they shall be so proportioned that the correct light center position will be obtained when used with the so-called "O" holder, which positions the top edge of the reflector ¾ of an inch below the center contact of the socket.

Art. 3. Diameter—For each size of reflector, the effective diameter (i e , the diameter of the surface well illuminated by the direct rays of the lamp) shall not be less than the values given in the final column of the following table. For convenience, the light center lengths of the MAZDA C lamps and the nominal over-all diameter of reflectors are also included.

Reflector Designation	MAZDA C Lamp Watts	Light Center Length Inches	Nominal Diameter	Effective Diameter
Dome 75	75	4 7/16	12	11¼
" 100	100–150	5 7/16	14	13¼
" 200	200	6	16	15¼
" 500	300–500	7	18	17
" 1000	750–1000	9½	20	19

Art. 4. Contour—The contour shall be such as to avoid undue concentration of light beneath the unit. That is, on photometric test the maximum candlepower of the unit, between 0 degrees and 15 degrees from the vertical axis shall not exceed by more than 15 per cent the average of the candlepower values at 25, 35 and 45 degrees when measured with a standard MAZDA C lamp having a filament of the sawtooth construction. In a lamp regarded as standard the end-on candlepower value should not exceed two-thirds of the mean spherical candlepower rating.

Art. 5. Efficiency—The design of the reflector, reflection factor of porcelain-enamel, etc., shall be such that, with the lamp filament so located as to give an angle of cut-off of 72½ degrees, the output of the complete unit shall be approximately 75 per cent or more of the light generated by the bare lamp. The minimum acceptable light output under the specifications shall be 70 per cent.

Art. 6. Acceptance Criterion—In judging the acceptability of any group of reflectors under these specifications a reasonable number of samples selected at random shall be examined, and if it is found that an appreciable number fail to comply with the specifications, the inspection shall be continued until a thoroughly representative sampling of the entire lot of reflectors involved has been completed. If more than 5 per cent of the samples so tested fail to comply with the specifications, the group of reflectors shall be considered inferior to these specifications. In view of the variability of the reflection factor of porcelain enamel and other possible deviations, the output of a manufacturer cannot be recognized as complying with these specifications unless checked at least four times a year by a thorough inspection and test of his stock, made as outlined above.

AMENDING SPECIFICATIONS.

These specifications may be amended and additional standard specifications adopted from time to time by joint action of the Research Laboratories of General Electric Company and the majority of the number of manufacturers whose product is at that time being regularly inspected, as provided in Article 2, by the Electrical Testing Laboratories.

RESEARCH LABORATORIES
GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.

Fig. 3.—Specifications.

This photometer has a concave reflecting surface of plaster of Paris or other suitable composition in the center of which a concentrated filament miniature lamp is supported by a plaster of Paris standard so located that when the reflector is placed on the photometer the light source will be in the same position with respect to the reflector as is the lamp filament when the reflector is in ordinary use. It will be noted from the diagram

of Figure 5 that the lamp is partly surrounded by a plaster of Paris shield. The purpose of this is to cut off all direct light from the lamp which would otherwise fall on the reflecting surface of the photometer, and at the same time to permit the direct rays to reach every point on the inner surface of the reflector.

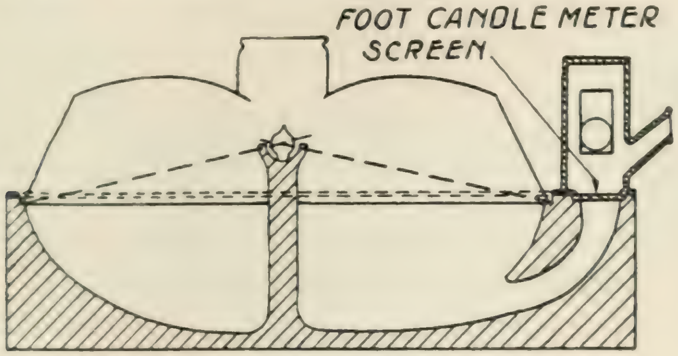


Fig. 5.—Reflector photometer diagram.

When a reflector is placed on the photometer, the light from the miniature lamp first strikes the reflector and is reflected down to the surface of the photometer and back again several times. A certain proportion of the light, however, finds its way through the passage of rectangular cross section (designated as A in Fig. 5) over which is placed a comparison screen similar to that used in the foot-candle meter. The light which reaches the under side of the screen illuminates it uniformly to an intensity which is dependent on the amount of light directed downward by the reflector. The upper side of the screen is illuminated to a graded intensity by a second miniature lamp located in a specially designed housing.

With this photometer the use of voltmeters or other instruments, is not required, for the two miniature lamps are operated in series; hence, variations in current or voltage in the circuit effect both lamps to the same extent, and any difference in illumination on one side of the screen is balanced by a corresponding difference on the other side. In order that the photometer may be operated from the ordinary 110-120 volt service connection, the miniature lamps chosen have been designed to operate at sixty volts.

The simplest use of the photometer is to determine whether one reflector of unknown quality is better or poorer than a standard reflector, that is, one whose reflection factor has been determined

from the distribution curve. The standard reflector is placed on the photometer, and, by viewing the comparison screen, the spot on the screen where the light intensity on the under side is equal to that on the upper side is determined and used as the reference point. If, when another reflector is placed on the photometer, the new screen reading is the same as the reference point, the reflection factor of the second reflector is the same as that of the standard. If the screen reading is higher or lower than the reference point, it is an indication that the reflection factor is correspondingly higher or lower. The scale may also be calibrated so as to read directly in terms of output for the complete unit.

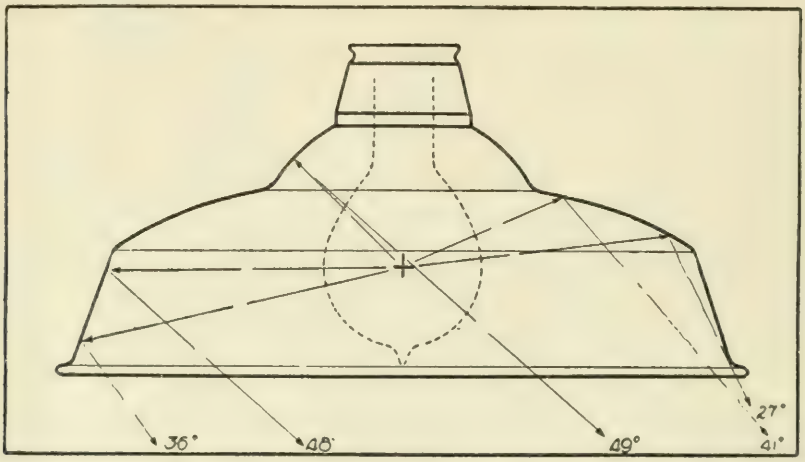


Fig. 7.—Contour R. L. M. Dome reflector showing absence of cross reflector.

A limitation of porcelain enamel is that no more than one-sixth of the light returned from its surface is regularly reflected as from a mirror; the rest is reflected diffusely, as from a depolished or mat surface, and its distribution is therefore to a large extent independent of the contour of a reflector of given diameter and depth. The degree of control which can be exercised over the distribution of light is therefore limited, but fortunately it is sufficient for most factory lighting requirements.

A typical RLM Standard dome reflector is illustrated in Figure 6. Its contour has been so developed that cross reflection at least of the specularly reflected rays is eliminated. So far as possible the light emitted by the lamp strikes the reflector but once and is then reflected down, Figure 7. Absorption is thus kept at the minimum practicable for a reflector of this depth and diameter.

380 a

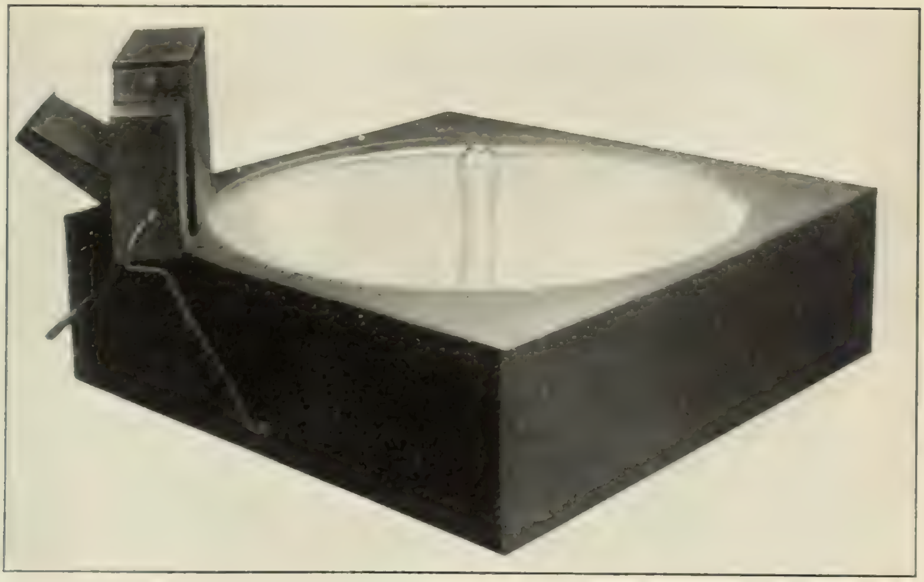


Fig. 4.—Reflector photometer.

Fig. 5.—R. L. M. standard dome reflector.

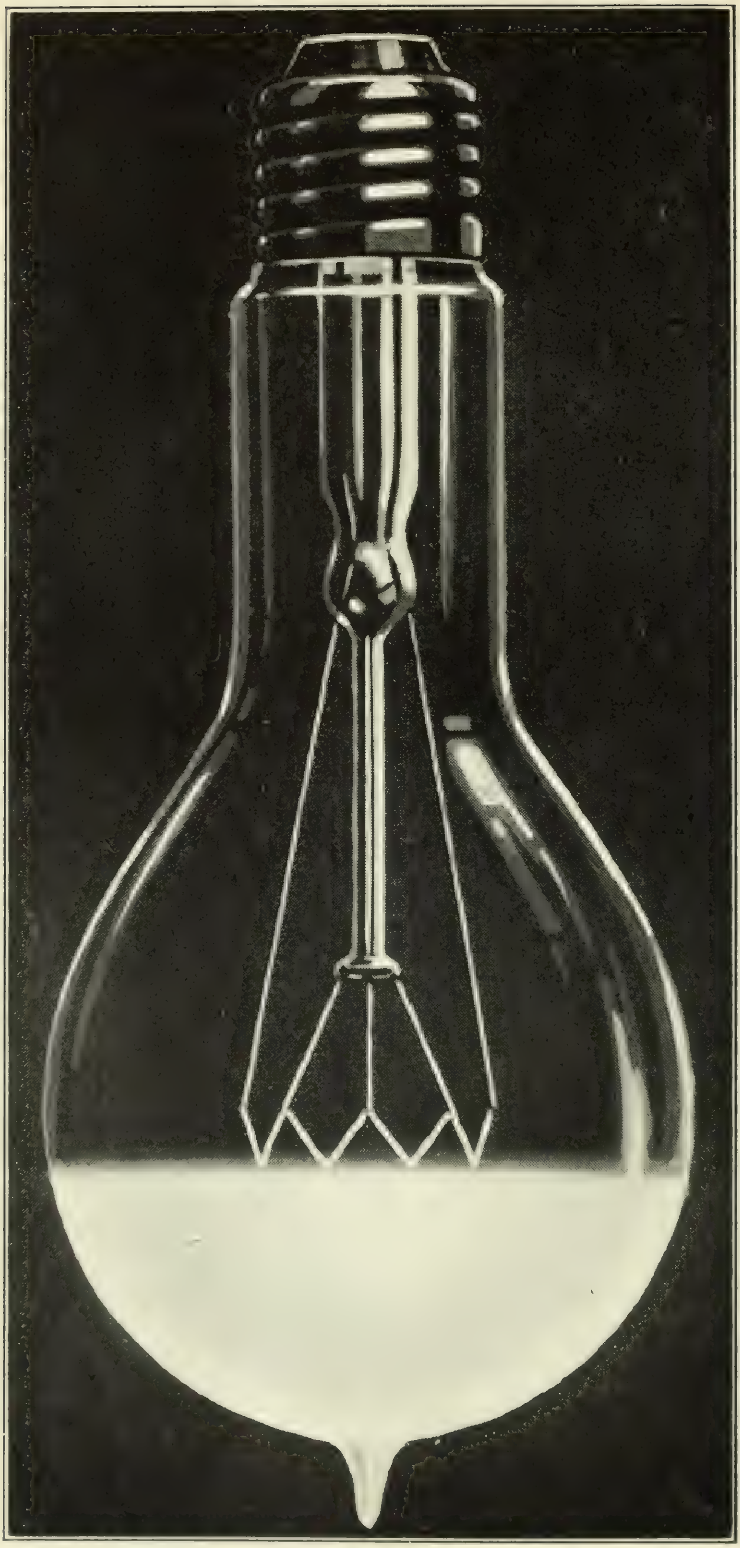


Fig. 10.—Bowl enameled lamp.

The specularly reflected light all escapes within the angles of 25 to 40 degrees from the nadir, thus building up the candlepower at the angles where it will assist in producing uniform illumination and also in preventing cross reflection.

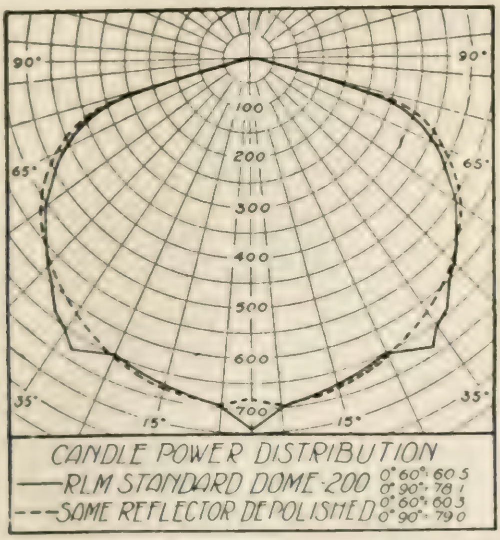


Fig. 8.—Photometric distribution curve of R. L. M. standard dome.

Figure 8 shows the photometric distribution curve of an RLM Standard dome reflector. The dotted line is the curve of the same reflector depolished. It will be noted that practically the only difference between these curves is that on the curve of the standard reflector some of the light from the higher angles is directed down to between 25 to 40 degrees; the total outputs are the same within the probable errors of photometry. The light distribution of the depolished reflector, Figure 9, Curve A, may be resolved into its two components, Curve B, the portion of the bare lamp flux between 0 and 72½ degrees, and Curve C, the light reflected from the porcelain enameled dome. It is of interest to note how closely Curve C approximates a circle, (Curve D), which, of course, would represent the distribution from a flat disk having a perfectly diffusing surface. In this case the lumens in Curve C total 69.2 per cent. of the lumens from the lamp which impinge upon the reflecting surface.

For most satisfactory results as to diffusion of light clear bulb Mazda C lamps should not be used with RLM Standard dome reflectors at mounting heights of less than 20 feet. At greater heights than this the nearest lamp within the usual field of vision

is so far removed that ordinarily the amount of light entering the eye directly from it is insufficient to cause glare; also the lighting unit subtends so small an angle at the working surface that shadows and specular reflections would not be greatly softened by rendering the lamp bulb diffusing. Bowl-frosting Mazda C lamps does not render them sufficiently diffusing so that they are

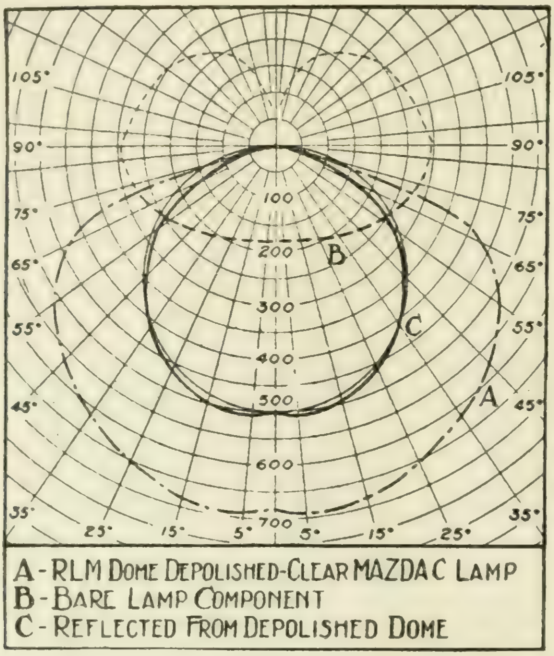


Fig. 9.—Components of distribution of depolished dome.

of the same order of brightness as the reflector; in other words, so that the entire light source appears of uniform brilliance. For this reason the bowl-enameled lamp (Figure 10) has been developed for use in dome reflectors. The enameling is a superficial coating which is applied to the bowl of the lamp and is carried to the point opposite the lowest part of the filament. As regards durability it will resist practically any mechanical abrasion it is likely to encounter. Repeated tests have shown it to be proof against deterioration by acid fumes. Because of its smoother surface, this lamp does not collect dirt as readily as a frosted lamp.

When used with the RLM Standard dome reflector, the lower part of the lamp becomes virtually a semi-indirect bowl serving the same purpose as heretofore has been accomplished by the opal cap. Its advantages over the opal cap are obvious. In con-

junction with the bowl-enameled lamp the RLM Standard dome

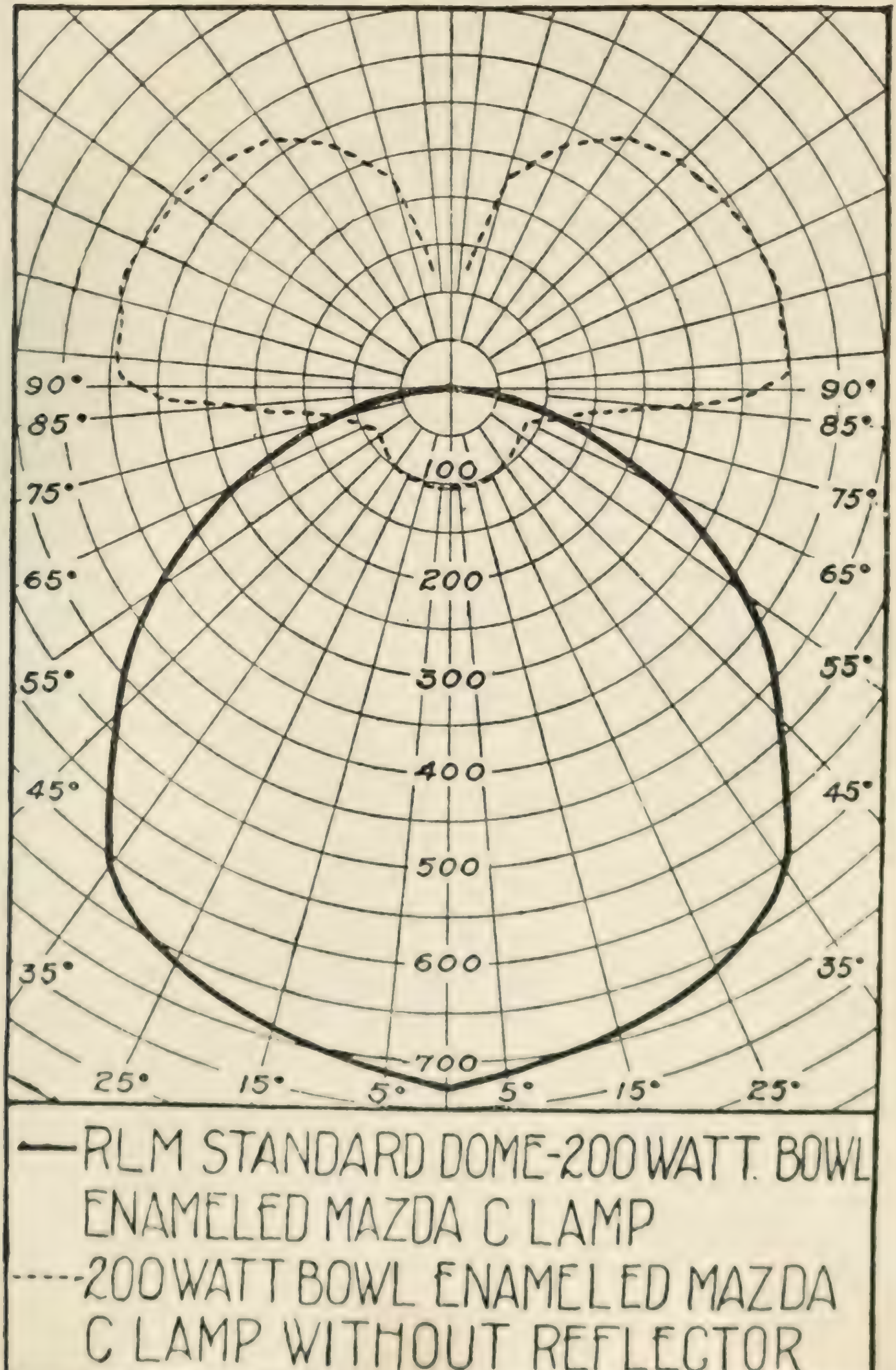


Fig. 11.—Photometric distribution curve R. L. M. standard dome and bowl enameled lamp.

reflector provides an equipment that will meet the requirements

of a large percentage of our industrial plants. This combination provides a unit in which glare is minimized, shadows softened, excellent diffusion is obtained, and maintenance is simplified. From the standpoint of absorption, the total output of an RLM dome reflector equipped with a bowl-enameled lamp is of the order of 10 to 12 per cent. less than for the same reflector equipped with a clear lamp, or expressing it another way, the output is approximately 65 per cent. of the total lumens of a bare clear bulb lamp.

In a paper, "Effective Lighting of Factories as Judged by Daylight Standards,"[1] the author suggested certain comparative ratings to show the merits of a number of types of reflecting and diffusing equipment in factory use. These ratings have been somewhat extended and revised in Table I which follows.

It will be noted that all the curves in this paper are based on the 200-watt lamp and are, therefore, comparable with those of earlier types which will be found in the paper mentioned above.[2] The 200-watt lamp now gives 3100 lumens, instead of 2920 as in 1917, therefore, in such a comparison a correctioon should be made for this fact.

In conclusion the author desires to express his appreciation of the assistance of the representatives of the reflector industry, and particularly of Mr. G. H. Stickney, through whose co-operation this development has been rendered possible.

TABLE I.

					R L M standard dome		
	Shallow dome reflector Clear lamp	Bowl reflector Clear	Metal reflector Diffusing Silver cap	Opal globe with reflector	Clear	Bowl frosted	Bowl enameled
% Clear Lamp Lumens Total				64			
Lower Hemisphere	77	65	55	58	75	71	65
Relative Illumination on Horizontal Surfaces	A	B+	B	B	A+	A	B+
Relative Illumination on Vertical Surfaces	A+	B	C+	B+	A+	A	B+
Direct Glare	D	C+	A	B	C	B	A
Reflected Glare	D	D	A	C+	D	C	B
Shadows	C+	C	A+	B+	C+	B	A
Maintenance	A+	A	C+	B+	A+	B+	A

A+ indicates	- - Best	C+ indicates	- - Fair
A "	- - Excellent	C "	- - Weak
B+ "	- - Very Good	D "	- - Condemned
B "	- - Good		

[1] TRANSACTIONS I. E. S., Vol. XII, No. 8, p. 417.

[2] TRANSACTIONS I. E. S., Vol. XII, No. 8, p. 416.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XV | OCTOBER 9, 1920 | NO. 7

ILLUMINATION BIBLIOGRAPHY.

The committee on education of 1913-1914, published a bibliography on illumination, which was combined with a summary of educational status. At the request of the council, the present committee has undertaken a revision of both these tables.

This bibliography has been brought up to June, 1920.

The following note is taken from the first edition; This table, which was first prepared by Mr. Norman D. Mcdonald, gives a classified analysis of all the available books, in English, pertaining to illuminating engineering. It indicates the possible utility of these books for illuminating engineering practise. The distributions under the various subject-headings constitute, of course, an index rather than a precise analysis of the contents of the books. Moreover, the classification, as might be expected, is necessarily more or less arbitrary. For example, "Private House Electric Lighting" by Taylor describes small plants for generation of electricity, and the practical wiring and placing of lamps in residences. It has been classed under the heading "G," but there are also good reasons for classing it under "D," "M," "Q," or "U."

CATALOG OF VARIOUS SUBJECTS COVERED BY TABLE I.

A. Physical basis of light production.
B. Physical characteristics of sources.
C. Chemistry of light production.
D. Electric illuminants.
E. Gas and oil illuminants.
F. Incandescent gas mantle lamps.
G. Electric and gas lighting (gen. mfgr. and dist.)
H. Units, standards and terminology.
I. Photometry.
J. Architecture.
K. Physiology and psychology.
L. Calculations.
M. Interior illumination.
N. Exterior illumination

O. Reflectors, glassware, etc.
P. Fixtures.
Q. Commercial aspects of electric and gas lighting.
R. The Illuminating Engineering Society.
S. Illuminating engineering.
T. Color.
U. Miscellaneous.

In the present revision, reference has been made to the United States Catalog for the intervening period, and to the catalogs of the most prominent publishers of technical and scientific works. As in the original analysis, articles which appeared in trade papers and current magazines have not been included in this survey. There are a number of publications, however, not included here, which should be brought to the attention of persons interested in the subject of illumination in any of its phases. These are the bulletins, booklets, catalogs, and other literature distributed by many of the large reflector and lamp manufacturers. The information contained therein, is for the most part reliable and instructive and will offer much assistance on questions regarding the modern design, the selection and the installation of lighting systems.

TABLE I. BIBLIOGRAPHY AND SUMMARY SHOWING APPROXIMATE NUMBER OF PAGES GIVEN TO VARIOUS TOPICS.

Illuminants.

Title	Author	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Arc Lamps and Accessory Apparatus	J. H. Johnson (1911)				110				11													
Electric Arcs	C. D. Child (1913)				180					10												
The Electric Arc	H. Aryton (1898)				443					14												
Electric Arc Lamps; their Principles, Construction and Working	Zeidler & Lustgarten (1908)				179				5													
Electric Lamps	M. Solomon (1912)	9	9		216				4	68												
Electric Lamps and Electric Lighting	J. A. Fleming (1894)		25		83			50						10								
High Efficiency Electric Illuminants and Illumination	R. W. Hutchinson, Jr. (1911)				170					7				60	24							7
Incandescent Electric Lamps and Their Application	D. H. Ogley (1914)	8			49				10	18		5	7									
Modern Illuminants and Illuminating Engineering	L. Gaster & J. S. Dow (1915)				38	21				66				92	39	50					38	109

Lighting Practise.

Title	Author	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
The American Practise of Gas Piping and Gas Lighting in Buildings	Wm. P. Gethard (1908)							249										9				
The Art of Illumination	L. Bell (1912)				68	23	17		25			24		72	55	37					12	
Artificial Light	M. Luckiesch (1920)	17		13	16	83						46		32	68			31			53	
Display Window Lighting and the City Beautiful	F. L. Godinez (1915)													157	14		25				16	
Electrical Illuminating Engineering	G. S. Barrows (2nd ed. 1908)				90				22	41			38			16				12		
Electricity for Everybody	R. B. Matthews (1912)																	300				
Electric Incandescent Lighting	Houston and Kennelly (2nd ed. 1902)				221			206		23										12		

Lighting Practise.—(Continued).

Title	Author	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Electric Lighting	F. B. Crocker (4th ed. 1901)				110			826										23				
Electric Lighting	O. J. Ferguson (1919)			16	23				49	46		5	28	33	21	13				4	3	2
Electric Lightiug and Its Practical Application	J.N. Schoolbred (1879)				30			27														
Electric Lighting and Miscellaneous Application of Electricity	W. S. Franklin (1912)				25			155		40				14	14	5						
Elementary Principles of Illumination and Artificial Lighting	A. Blok (1914)	12	12						19				43	35	31	13				23		
Elements of Electric Lighting	P. Atkinson (10th ed. 1901)	221			53																	
Factory Lighting	C. E. Clewell (1913)													156								
Gas Analyst's Manual	J. Abady (1902)								31	96												396
Gas Centenary Lectures	American Gas Institute (1912)					50		100														25
General Lectures on Electrical Engineering	C. P. Steinmetz (1910)	30			20																	
Illuminating Engineering Practise	Joint Lectures by Univ. of Penn. & I. E. S. (1916)					18				72	14		36	174	142	30					30	
Lighting by Acetylene	F. Dye (1902)							182														
The Lighting Art	M. Luckiesh (1917)										9		13	48	8		10				61	76
The Lighting Book	F. L. Godinez (1913)											31		69		10						
Modern Illumination: Theory and Practise	Horstman and Tousley (2nd ed. 1916)				40					24		14		40	5	15	3			83		30
Obstruction to Light	H. B. Molesworth (1902)																					300

Lighting Practise.—(Continued).

Title	Author	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
The Orientation of buildings or Planning for Sunlight	Wm. Atkinson (1st ed. 1912)																					139
Practical Electric Illumination	T. W. Croft (1917)				38				72				30	40	14	18						
Practical Illumination	Cravath and Lansingh (1907)	4	4		39	16						4	12	204		55						
Private House Electric Lighting	F. H. Taylor (1911)							144														
Residential Lighting	W. A. Morris (1915) (Proceed. Intern. Gas Congress)																					
Science of Illumination	Dr. L. Block (1914)		24						10	24			82	74						7		
Street Lighting	G. S. Barrows (1915) (Proceed. Intern. Gas Congress)														25							
Tables for Computation of Illumination	W. B. King (1908)												20									

Photometric Measurements.

Title	Author	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Electrical Photometry and Illumination	H. Bohle (1912)	20			35				14	47			30			12				43		
Illumination and Photometry	Wm. E. Wickenden (1st ed. 1910)	11			43	14			12	37		9	12		6	9				19		
Illumination: Its Distribution and Measurement	A. P. Trotter (1911)								26	226										37		
Light, Photometry and Illumination	W. E. Barrows, Jr. (1912)	17							27	69		19	112	34	22						12	
Photometrical Measurements	W. M. Stine (1909)	27			10				108	103		12										
Photometry of the Gas Filled Lamp	Scientific Paper No. 264, U. S. Stand. (1916)									17												
A Treatise on Industrial Photometry with Special Application to Electric Lighting	A. Palag (1896)									310												

Introduction to Study of Color Phenomena	J. W. Lovibond (1905)																				46 23	
Light	R. C. Maclaurin (1909)	223																				
Light: A Course in Experimental Optics	L. Wright (1892)	400																				
Light: Its Influence Upon Life and Health	F. Winslow (1867)											300										
Light: Visible and Invisible	S. P. Thompson (1897)		245									45										
Light and Shade: Their Applications	M. Luckiesh (1917)	231										22									9	
The Nature of Light: With a General Account of Physical Optics	Dr. E. Lommel (1892)	352																				
Outlines of Applied Optics	P. G. Nutting (1912)	200	10							14		4										
Optic Projection	Gage and Gage (1914)																					703
Physical Optics	R. W. Wood (1911)	600																				
Spectrum Analysis	J. Landaueer (1st ed., 1898)		10																			
Studies in Light Production	R. A. Houston (1912)		20		33	15			13	14												11
The Theory of Light: A Treatise of Physical Optics	R. C. Maclaurin (1908)	160											160									
A Treatise on Light	R. A. Houston (1915)	466																				
Principals and Theory of Illumination.																						
Color and Its Applications	M. Luckiesh (1915)																				343	
Color Symposium	C. E. Ferree (1917)																				61	
Color Value	C. R. Clifford (1907)																				90	
Color Vision	Capt. W. de W. Abney (1894)											220									8	
The Electric Light: Its History, Production and Application	Alglave and Boulard (1884)				177	10		176										50				
The Language of Color	M. Luckiesh (1918)																				281	
Lectures on Illuminating Engineering	Johns Hopkins Lectures (1910)	24	72	16	48	60	20	150	24	96	18	80		90	90	46	14	95				7
Light and Electricity	J. Tyndall (1874)	194																				
Light, Radiation and Illumination	P. Högner (1906)	56																				
Radiation, Light and Illumination	C. P. Steinmetz (3rd ed., 1918)	77	24	3	33	20				20		44	14			24				50	5	
Students' Text Book of Color	O. M. Rood (1908)											30									325	

Specialties.

Title	Author	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Color Matching on Textiles	D. Patterson (1901)											10									130	
The Colorado Springs Controversy	H. Floy (1st 1908)																	317				
Electric Light for the Farm	N. H. Schneider (1911)							85														
Electric Lighting for Marine Engineers	S. F. Walker (1892)																	293				
Electric Ship Lighting	J. W. Urquhart (1892)																	269				
Light Reflecting Values of White and Colored Paints	H. A. Gardner (1916)																				13	
The Range of Electric Searchlight Projectors	J. Ray (1917)				145																	
Searchlights: Their Theory, Construction and Application	F. Nerz (1907)				135																	
	Totals	3342	455	35	2884	247	37	2350	482	1502	41	878	637	1402	510	353	52	1356	0	290	1506	1805
Per cent of total number of Pages		16.6	2.2	0.2	14.3	1.2	0.2	11.7	2.4	7.5	0.2	4.4	3.2	6.9	2.5	1.7	0.3	6.7	0	1.4	7.5	8.9

MONOGRAPH ON ILLUMINATION.*

BY GEO. A. HOADLEY, PAST PRESIDENT I. E. S.

THE BEGINNINGS OF ILLUMINATION.

Some one has said that man is distinguished from other animals by his ability to control fire. An equally true statement would be this, that he differs from other animals by his ability to produce and control artificial light.

Men of the Stone Age knew no light at night but that of the moon, planets and stars, except the blinding flash that broke with a crash from the clouds.

When man became a Cave Man, however, and learned the art of producing fire in his cave (Fig. 1) he found that it gave him not only an agreeable warmth but a pleasing and cheerful light that made the cave a very haven of refuge from the darkness and terrors of the night outside.

We do not know how the first fire and light were produced by this man. It may have been by carefully preserving the burning wood from a tree fired by the lightning (Fig. 2). It may have been that he noticed the spark of fire caused when he threw a stone at some night prowler, missed it, but struck another stone and from this got the idea of the first flint and tinder. It may have been that he noticed the warmth caused when he rubbed his hands together on a cold day and then developed the original fire stick (Fig. 3).

In whatever way it was that he discovered fire and its attendant light he found himself with a most valuable tool for both his protection and his comfort.

Having made this first and greatest step in producing light the next thing was to devise some form of it that he could take out of the cave to light his path through the woods at night.

This brought out the torch made of pine knots found in the refuse from decaying logs. These small knots (Fig. 4), dried, split and fastened in a bundle made a brilliant torch and served

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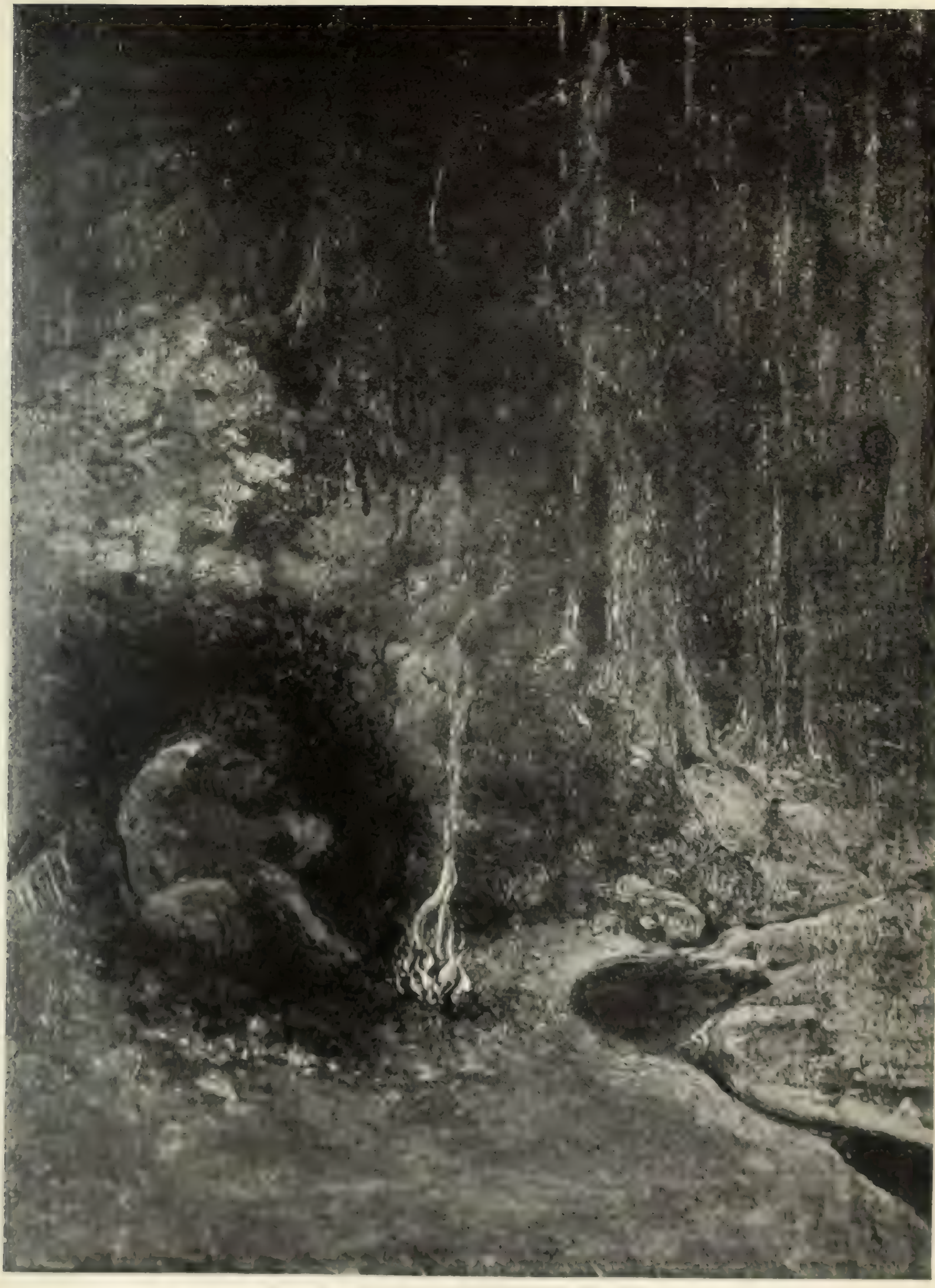

Fig. 1.—The cave man's light. (Courtesy General Electric Co.)

to drive away wild beasts as well as to point out the way to and from his cave.

The hunter, roasting his game in the fire, noticed that the fat which dripped into the coals burned vigorously giving out a deal of heat and light, so collecting some of the dripping fat in a shell or hollow stone he set it on fire and saw that it would burn of itself and then, by adding a wick of shredded bark, he had the first lamp.

This was a satisfactory lamp but was not as portable as he wished it to be and so he covered the bark wick with a coating of tallow from the fat of a deer or sheep and when this had hardened he had the first candle.

The lamps and candles which sprung from such simple beginnings were the only forms of light for illumination for many centuries. It is true that many substances went into the making of the candle. Beef tallow was one of the first, later beeswax and other kinds of wax were used. Paraffin and sperm candles became common and the light given by the latter was adopted as the first practical unit of lighting.

One kind of candle used in country homes was the tallow dip, made by dipping the proper length of candle wicking into melted tallow and hanging it up by one end to cool. By repeated dippings and coolings the candle was increased to the desired size and was then ready for use.

A more symmetrical form was the molded candle. This was made in a mold like that shown in Fig. 5. A small stick was placed across the top of the pan for the purpose of holding the wicking in place. This was doubled and threaded through each tapering mold, looped over the stick at the top, drawn tight and fastened at the bottom. Melted tallow was then poured into the pan and the mold set away to cool.

The light from the candle is soft and agreeable though not very brilliant. To obtain good illumination many candles were burned, as was the case when Washington's birthday was celebrated in 1817 in Washington Hall, Philadelphia, when 2000 candles were used. The records of the time say that the room was brilliantly lighted. Probably it was much less brilliant than a room used for such a purpose would be at the present time but it is also probable

that it was less trying to the eyes and more agreeable than the latter would be.

The necessity for some form of artificial illumination lead to the use of many kinds of illuminants. One of these was the rush light made from the pith of the candle-rush, so named from this use made of it. Another is the candle berry, the fruit of the wax-myrtle, a shrub common along the eastern coast of the United States (Fig. 6). The berries were sometimes mounted on a reed and then burned as candles. The wax is also collected by boiling the berries in water when it will rise to the top. On cooling it is made into the aromatic bayberry candles that are now used more as an ornamental source of light than as sources of illumination.

Perhaps the most peculiar source of light is the candle-fish. This is a small round fish so oily in its nature that on being dried and having the pith of a reed thrust through it for a wick, it served as a practical form of candle for the Indians of New England. It is still used for this purpose by the South Sea Islanders and is called by them the Olichan.

EARLY FORMS OF LAMPS.

Coincident with the development of the candle there was the greater development of the lamp. There was an opportunity for this greater development on account of the more permanent character of the lamp.

When a candle burns the candle itself is consumed but when a lamp burns it is only the oil in the lamp that is lost, the lamp itself remains.

That the lamp is of early origin is shown by the references to it in early historical writings and by its being pictured on ancient monuments which shows that it was well developed at the time they were built.

Both the candle and lamp have always held an important place in religious ceremonies. The term candle, however, is often used in the Bible for either a candle or lamp.

The Golden Candlestick made by Moses for the tabernacle was a standard having seven branches, each of which carried a lamp at its upper end (Fig. 7).

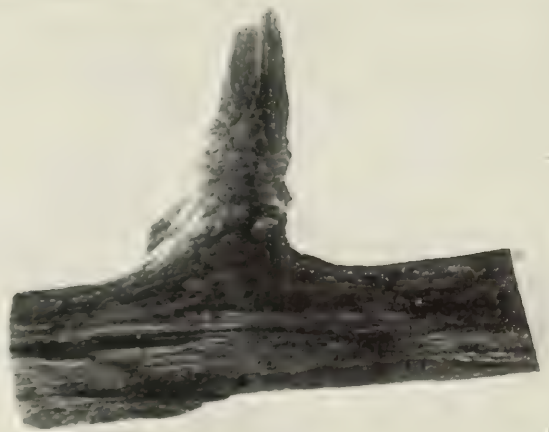

Fig. [illegible].—Flash from the clouds.

Fig. 3.—Fire stick in several forms.

Fig. 4.—Pine knot.

Fig. 5.—Candle molds.

Fig. [illegible].—Candle berry.

Fig. 7.—Supposed form of golden candlestick.

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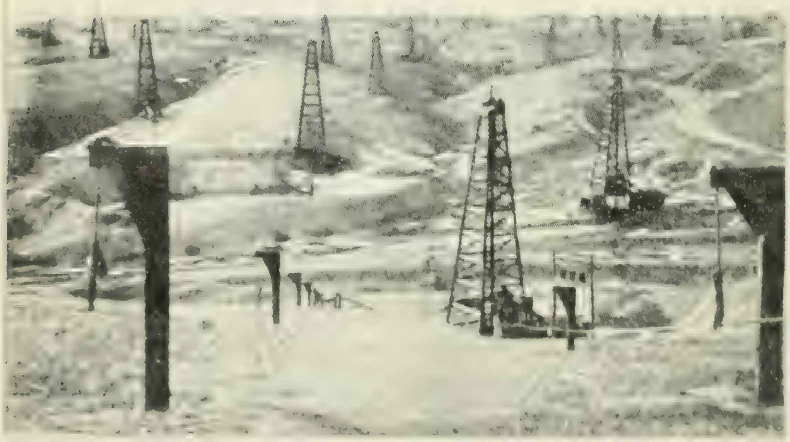


Fig. 8.—Roman terra cotta lamp, time of Augustus. Fig. 9.—Opening a gusher. Fig. 10—Oil field.

While lamps are mentioned in many parts of the early books of the Bible as well known sources of illumination the most vivid description of their use and the one that is the easiest for us to understand is the one brought out in the very human story of the ten virgins who went out to take part in wedding festivities. These girls were just like the people of to-day, part were wise, went prepared and succeeded while the rest trusted to luck and failed.

The first forms of lamps were probably copies of natural shells and skulls of small animals. These were molded from clay and

Developments in pottery and afterward in metal resulted not only in more accurate imitations but in very elaborate and intricate designs that became more ornamental as the skill of the designer improved.

This is shown in the lamps of the early Greeks and Romans (Fig. 8) while a considerable variation in the forms of lamps is shown in those excavated from the ruins of Herculaneum and Pompeii.

Animal fats and fish oils were burned in the first lamps but afterward oils pressed from vegetable seeds and nuts were used as well as that obtained from olives. These lamps were frequently made to give out perfumes as well as light by putting certain spices in the oil so that it would give out a pleasant fragrance on burning.

This was particularly the case with lamps used in religious ceremonies in which the incense was of as great importance as the light.

As lamps became larger they gave off more light but for thousands of years there was no source of illumination that could compare in brilliancy with the sources of to-day.

A change was made in the lighting of the New England colonies when the first cargo of whale oil was brought in in 1690. This oil became the main source of supply for lamps for many years until the destruction of whales for the purpose of getting their oil so reduced their numbers that the oil became more and more costly and finally many of the whalers, finding whales difficult to get and profits small, stopped the business.

The resulting lack of oil for illumination was relieved somewhat by the use of camphine mixed with alcohol as an illumi-

nating fluid. Camphine is a rectified oil of turpentine made by distilling it over lime to free it from rosin in order to reduce the amount of smoke given off in burning. An additional help in the complete combustion of this illuminant was secured by the use of a hollow wick through which a draft of air was forced by a fan placed in the base of the lamp and run by clockwork.

THE DISCOVERY OF PETROLEUM IN THE UNITED STATES.

It was in 1859, fifteen years after the first use of camphine as an illuminant, that petroleum was first obtained from a well.

In that year Mr. E. L. Drake, having observed petroleum floating on the surface of streams and pools of water in Titusville, Pennsylvania, determined to make an attempt to find it by boring a well. It had previously been obtained in small quantities from wells bored for salt water.

No one believed it possible to get oil in quantity by this method, but on August 21, having then reached the depth of 36 ft., his well begun to flow at the rate of 1000 gallons per day. This was the beginning of an industry that has covered all parts of the inhabited earth with products that are more used than any other material as a source of illumination.

One of the advantages possessed by both the candle and the oil lamp is that they are self contained, that is they furnish in themselves the material for light production, the candle by burning its own substance and the lamp by burning the oil which it contains. Nearly all the forms in which lamps are made are also portable, the simple hand kerosene lamp (Fig. 11) being an example.

These two advantages are possessed by but few of the more brilliant sources of illumination that have been substituted for them.

MODERN SOURCES OF ILLUMINATION.

The more modern sources of illumination are of two kinds, gas and electricity. With the exception of the flash lamp or battery lamp, the lamps of neither of these are self contained since the gas lamp must be connected to a gas container by means of a system of pipes and the electric lamp to a generator by means of conducting wires. Neither are they portable to more than a limited extent. They are, however, much more brilliant sources of

illumination and have the great advantage that, on being installed in a house they can be "turned on" or "turned off," that is, both lighted and put out at either the lamp itself or at some remote station.

If the flame of a candle is studied it will be observed that the light comes from the burning of a gas that is given out from the melted tallow or wax as a result of the heat generated in the burning. In the middle just above the wick, a dark space will be seen. This is filled with gas from the wax and is comparatively cool.

(a) Fig. 11 (b)
(a) A candle flame.
(b) Simple kerosene oil lamp.

Around this space the gas is burning and the light comes from the outer part of the flame where the particles of carbon given up by the gas are heated to incandescence. In the same way the flames that are so effective in a wood fire are the burning gases given out by the heated wood.

ILLUMINATING GAS FIRST USED.

Of the two great modern illuminants gas was the first to be used. The earliest record of its use was in 1782 when William Murdock, an English engineer, devised a method of making gas

in sufficient quantities to be used for illuminating purposes and lighted both his house and garden with it.

The first proposition to use gas for illumination met with almost universal ridicule. This was expressed by Sir Walter Scott when he said: "There is a madman in London proposing to light London with—what do you think? Smoke!" People could not understand the possibility of bringing cold gas through a cold iron pipe and burning it at the end. They thought the pipes would be hot throughout and set the buildings on fire.

The first gas lights ever seen in America were shown in Philadelphia when in August, 1796, Ambroise and Company, makers of fireworks on Arch Street, bent pipes in various shapes, pierced them with rows of small holes and lighted the gas, thus forming groups of lighted figures.

This demonstration showed the possibility of using gas as an illuminant and in 1816 it was first introduced for interior illumination in this country by Charles W. Peale, father of Rembrant Peale, who at that time lighted his museum with gas. During the same year the Philadelphia city council visited the Chestnut Street Opera House to inspect its novel system of lighting by gas.

COMMERCIAL GAS WORKS ESTABLISHED.

These demonstrations of the practicability of gas lighting led other cities to become interested in the subject and Baltimore built its first gas works, the first in the United States in 1817, a little more than one hundred years ago. A municipal gas plant was established soon afterward in New York, and in 1835 Philadelphia built its first gas works.

While improvements were being made in interior illumination the lighting of the streets was not wholly neglected. Benjamin Franklin wrote in reference to this subject: "It was through a private person, the late John Clifton, giving a sample of the utility of lamps by placing one at his door, that the people were first impressed with the idea of lighting the city." But in general the darkness of the streets made it necessary to carry a lantern at night or to employ some one to carry a torch or "link" to lighten the way. These torch bearers were called link boys and their occupation gave rise to the saying: "You can't hold a candle to him."

While torches, candles, whale oil lamps, kerosene lamps and gasoline lamps have all been used for street lighting none of these sources of light was entirely satisfactory for the reason that they were all independent units.

It was not until a system was adopted that had a central plant like the gas or electric plants with radiating feeders that connected each lamp to the main plant, that street lighting became at all satisfactory.

Gas lighting was the first to occupy this field. This was done against the vigorous protests of many citizens who had an erroneous idea about the poisonous qualities of gas and the dangers in using it.

The first gas lamps were various forms of open lamps in which the gas was burned without a chimney (Fig. 12).

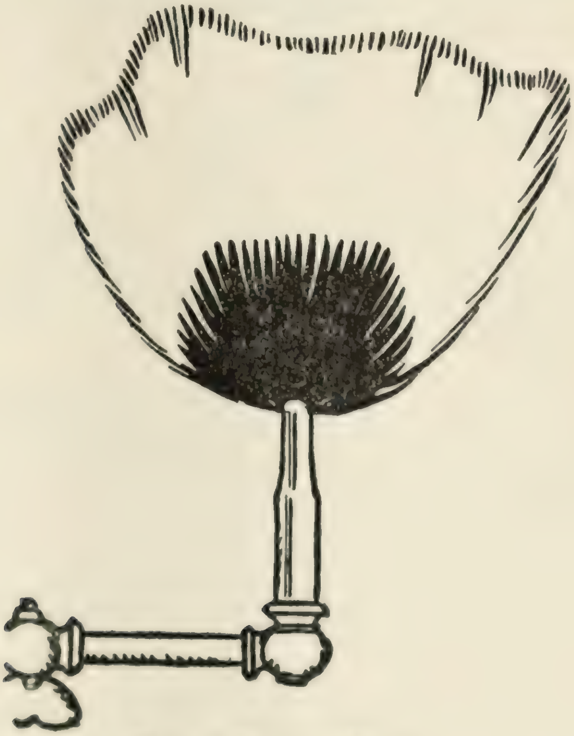


Fig. 12.—Open gas flame.

Chimneys and globes were gradually introduced to protect the flames from currents of air.

ILLUMINATION BY INCANDESCENCE.

Thus far only those sources of illumination have been considered in which the light is produced by the burning and consequent

destruction of the substance used. In the year 1826 Henry Drummond discovered that by raising a piece of lime to a high temperature it becomes incandescent, gives out a very brilliant light and is not consumed in the process.

To-day the greater part of our illumination is from some form of incandescent light. The Drummond light, the oxyhydrogen or limelight (Fig. 13) as it is called, was far too brilliant for ordinary use but provided a most satisfactory source of light for the projecting lantern.

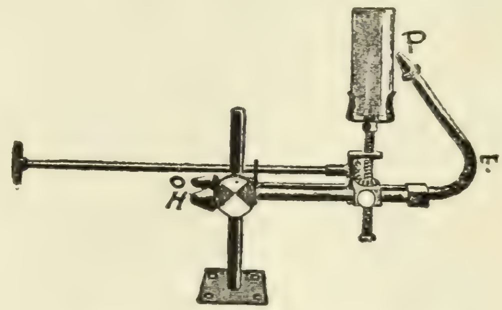


Fig. 13.—Oxyhydrogen lime light.

In the lamp shown, the gases oxygen and hydrogen are introduced through the pipes *O* and *H* and are mixed in *T*. They burn at *P* heating the lime at that point, producing a brilliant illumination.

The success of this light caused those who were interested in better illumination to search for some other substance than lime and for some other method of heating it than by the use of the oxyhydrogen flame.

The requirements for a substance to be used for incandescent lighting are that it shall have a very high melting point and that it shall be non-combustible.

MAKING INCANDESCENT GAS MANTLES.

While engaged in the search for such a substance Dr. Carl Auer, of Welsbach, made a discovery that has revolutionized the methods of lighting by gas.

This discovery was that if a web of cotton is soaked in a solution of certain chemicals derived from what are known as the rare earths, is then dried and set on fire, an ashy skeleton will

be left that retains the structure of the cotton and on being heated in a Bunsen flame will become incandescent.

This was the origin of the Welsbach mantle which has become the most important part of the present gas lamp.

After years of development the fundamental operation in the manufacture of a mantle for incandescent gas lighting consists, first, in the selection of a suitable fiber basis for the mantle.

The sole purpose of this fiber is to give form and strength to the ash that is to become the source of the illumination. The fiber used is spun into a thread and this thread is knit on a machine designed to knit in a cylindrical form, into an endless web (Feb. 14). The web is then cut into the required lengths, immersed in a bath of thorium and cerium nitrates (Fig. 15), then dried and shaped, after which it is subjected to the temperature of a Bunsen flame. This burns out the original fabric and leaves an ash which retains the form of the fabric and is composed of 99 per cent. thorium oxide and 1 per cent cerium oxide. (Fig. 16) after which they are given their final shape, are trimmed and inspected (Fig. 17) and then dipped in a collodion bath which, on drying, gives them strength to withstand the shocks of shipment.

The user of the mantle sets the collodion on fire and after it has completely burned off, the mantle is ready for the Bunsen flame, incandescence and illumination.

The physical strength of the mantle ash is of great importance in the life of the mantle and depends upon the strength of the original fiber. The stronger the fiber the stronger the ash.

Three kinds of fibers are used: cotton (Fig. 18, top), the individual fibers of which are capillary tubes not much exceeding one inch in length; ramie (Fig. 18, center), the fibers of which are solid and from four to eight inches long; and artificial silk, which is a cellulose dissolved in a suitable solvent and squirted under pressure through small openings. This fiber is solid and of any required length (Fig. 18, bottom).

The advantageous features of the artificial silk mantle are, its strength, a mantle being able to support a weight of from 40 to 50 grams and its absolute freedom from shrinkage. These qualities are most important for its use in upright mantles.

MANTLE GAS LAMPS.

In order that a lamp shall be highly efficient there must be an accurate adjustment between the form of the flame and that of the mantle so that it shall be incandescent over its entire surface. This adjustment has been worked out in a practical way for a number of new forms of lamps of which the Reflex is one (Fig. 19).

This lamp is of a new type containing an inner metal stack in an ornamental casing and makes use of a smaller inverted mantle than those previously employed. It is equipped with a newly designed Bunsen burner and is so ventilated that the metal supports will not tarnish.

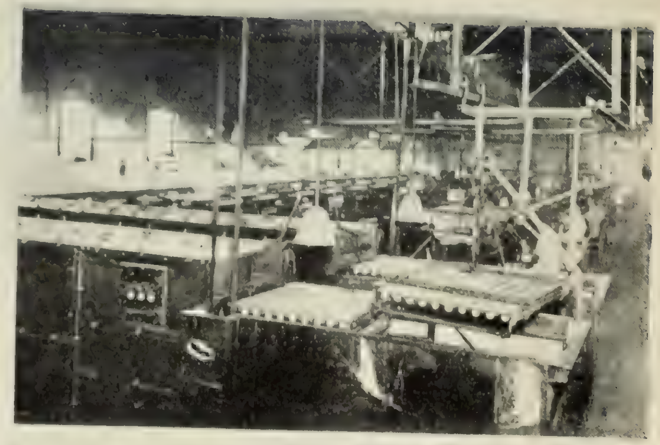
The advent of the mantle gas lamp gave rise to a demand for some form of this lamp that could be used to replace the existing flame burner without disturbing its connection to the feed pipes. This was accomplished by the use of an inverted U-tube which supported an inverted mantle burner. This form while furnishing a good light, took up considerable space and if used in a chandelier destroyed its symmetry.

A new form of lamp for this purpose was devised (Fig. 20) and called the "C. E. Z." This lamp can be used on the vertical connection without change and provides an artistic and highly efficient source of illumination. The lamp consists of an upright tube containing the raceway and mixing tube from the top of which extend horizontally three branch tubes, each bent downward at the end that contains the orifice and a screw support for the mantle.

The pilot light consists of a ring of small flames that insure the lighting of all three Bunsens. When lighted without the mantles the Bunsens provide three short, well pointed flames.

The mantles used are of the new rag type (Fig. 21), that is they are artificial silk mantles which have been dipped in the lighting solution but have neither been burned to ash nor hardened. The mantle is perfectly flexible and can be carried in the pocket without injury. Each mantle is fastened to a ring which screws onto the outside of the Bunsen orifice tubes.

After being screwed on the mantle is shaped by being blown out by unlighted gas. The gas is then turned off and the mantle



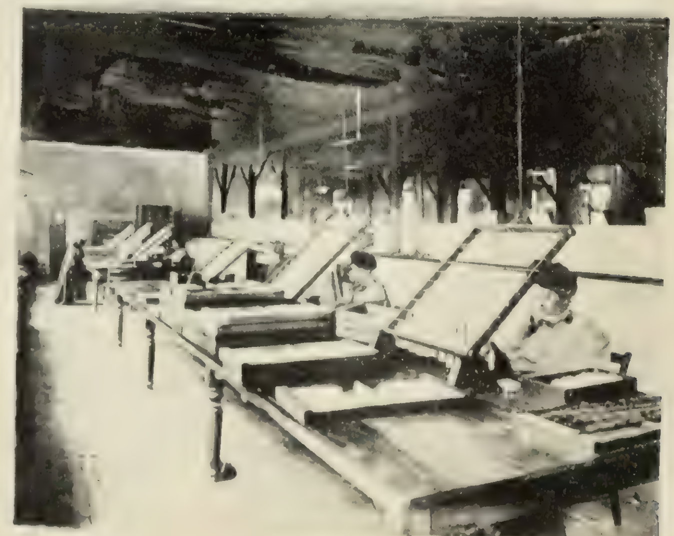


Fig. 14.—Knitting the web. Fig. 15.—Dipping inverted mantles. Fig. 16.—Hardening machines. Fig. 17.—Trimming & inspecting.
Fig. 18.—Microphotograph of fibers. Top. Cotton. Center. Ramie. Bottom. Artificial Silk.

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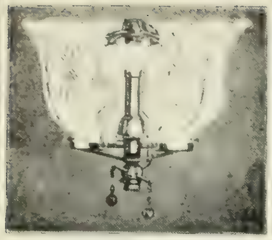
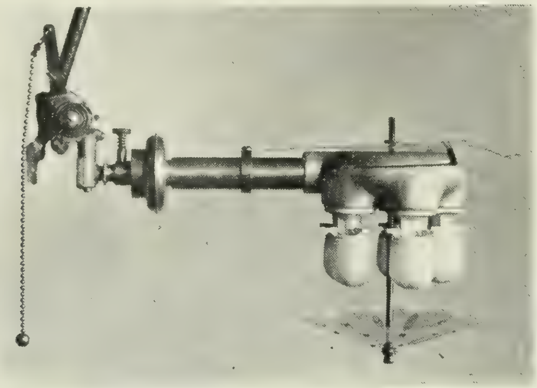
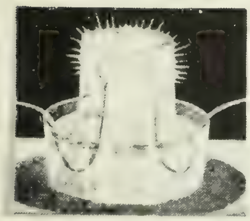
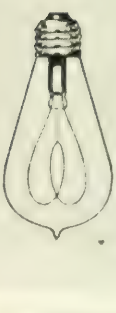






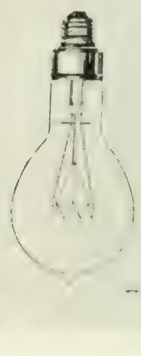


Fig. 19.—Reflex Lamp. Fig. 20.—C.E.Z. lamp. Fig. 21.—C.E.Z. mantle. Fig 22.—Kinetic gas burner.
Fig. 24.—Grove's incandescent lamp of 1840. Fig. 25.—Edison's first lamp factory.
Fig. 26.—Edison's first lamp of 1879. Fig. 27.—Gem lamp. Fig. 29.—The stem. Fig. 30.—The mount.
Fig. 31.—The bulb. Fig. 32.—Tubulation. Fig. 33.—Sealing in. Fig. 34.—Exhausting
Fig. 35.—Inserting base. Fig. 36.—Mazda C. lamp.

lighted with a match. After being thoroughly burned off the lamp is lighted in the usual way.

These lamps burn perfectly without inclosing glassware but since each mantle gives 30 candlepower per cubic foot of gas consumed per hour, the brilliancy of the cluster is so great that some form of diffusing shade is desirable. These are made in such fashion as to add to the artistic effect of the lamp.

A notable improvement has been made in the larger lamps for interior illumination by the discovery of the advantage of the horizontal Bunsen construction.

The burner (Fig. 22) consists of a long horizontal raceway and mixing tube terminated by a cluster of vertical Bunsens extending downward. By the use of short mantles a shallow bowl (Fig. 23) can be used, entirely concealing the lamp, while the use of a specially formed baffle plate of mica, placed above the lamp but within the bowl, so diverts the products of combustion in a horizontal direction that they are deposited on neither the lamp suspension nor the ceiling.

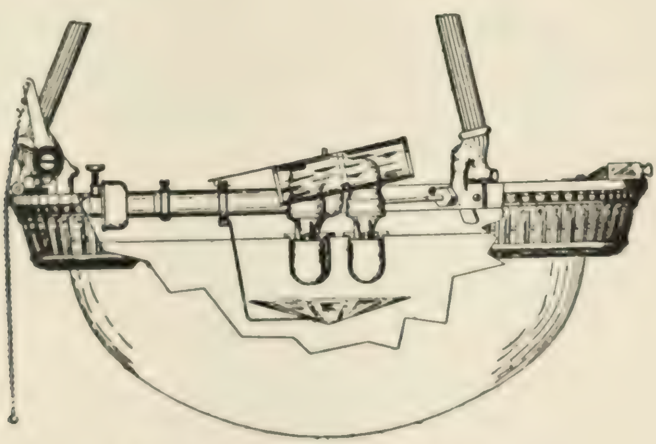


Fig. 23.—Large gas mantle lamp.

A mica baffle plate placed below the mantle cluster protects the bowl from the effects of the lengthened Bunsen flame that would result from a broken mantle.

ELECTRICAL SOURCES OF LIGHT.

While these improvements were being perfected in gas lamps, discoveries and inventions were being made in a different field that were destined to produce a vigorous rivalry between these sources of illumination.

The new agent was electricity. By connecting a number of voltaic cells in series to form a battery and touching the ends of the connecting wires together it was found that the wires were melted at the ends with a considerable flash of light. On fastening carbon pencils to the ends of the wires and sending the current through them a brilliant light in the form of a slightly curved arc was the result.

This was the origin of the electric arc as used in illumination. The light from these carbon arcs was so intense that while they were well adapted for street lighting they were far too brilliant for interior lighting and a form of electric light that would be adapted to this purpose was desired.

It was already known that a piece of platinum wire when heated in the flame of a Bunsen burner became incandescent and when the experiment of sending a sufficient current of electricity through such a wire was made it was found that the wire could be brought to incandescence by this means (Fig. 24).

While platinum had the required high melting point it was too expensive to be used in the production of a reasonably inexpensive lamp and since no other metal was then known that would meet both the requirements of high melting point and cheapness, recourse was had to a filament of carbon.

This was cheap and practically non-fusible but would be consumed at a much lower temperature than that required for incandescence. This made it necessary to inclose the filament in an exhausted globe or bulb.

Exhaustive experiments for the purpose of finding some satisfactory material for the basis of the carbon filament were made by Thomas A. Edison at his first lamp factory (Fig. 25) about the same time that the Welsbach mantle was being developed and since that time a rivalry between these two systems has gone on, leading to much greater progress in each than would have been probable without it.

This rivalry was at first unfriendly, but as the systems were developed and the magnitude and importance of illuminating problems became better understood, it was changed into a friendly competition in the methods of producing better lighting.

DEVELOPMENT OF THE INCANDESCENT ELECTRIC LAMP.

Edison's first lamp filaments were single loops of carbonized paper (Fig. 26). Carbonized bamboo was then used and afterwards the present carbon filament which is made by dissolving absorbent cotton in a solution of zinc chloride. A thick viscous liquid is formed which is forced through a die, thus forming an endless thread-like filament which is dried, wound into the required shape and carbonized by being brought to a high temperature in a furnace.

These carbon filaments served their purpose for many years, reaching their highest development in the metallized filament of the Gem lamp (Fig. 27).

It is a rather remarkable circumstance that the most recent form of the incandescent lamp has gone back to a metal filament, tungsten, instead of platinum and makes use of a non-vacuum or nitrogen-filled bulb.

The term Mazda, from the Persian meaning the supreme good, is used as the name for an incandescent electric lamp that has reached the highest present state of development. To secure this result many different materials are used in the making of the lamp (Fig. 28), some of them being very rare and expensive. The

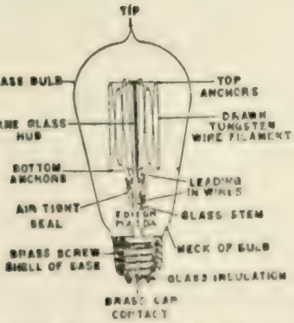


Fig. 28.—Principal parts of a Mazda lamp.

tungsten wire is made by compressing particles of pure tungsten under hydraulic pressure. After repeated heatings and pressures it is drawn into fine wire through diamond dies. It is then very ductile and has a high tensile strength, being stronger even than piano wire.

The stem (Fig. 29) of the Mazda B lamp, which is a tungsten vacuum lamp, consists of a glass tube through which the leading-in wires are run. The tube is flared at one end where it will

finally be joined to the neck of the bulb, while at the other end it is pressed about the leading-in wires, forming an air tight seal. At the time this seal is made a glass hub is welded to the stem. The purpose of this hub is to support and insulate the anchors on which the filament will be draped. After the insertion of the anchors the proper diameter of tungsten wire is selected for the filament, depending on the amperes desired and this is cut to the proper length for the voltage required.

One end is clamped to one of the leading-in wires and the filament is wound back and forth over the anchors until the end meets and is clamped to the other leading-in wire. This gives what is known as the "complete mount" (Fig. 30).

The manufacture of the bulbs is a complete industry in itself, requiring large plants and skilled glass blowers. As received from the glass works the bulbs have considerable superfluous glass at the neck which has to be cut off (Fig. 31).

The next process is that of tubulation which consists in melting a hole in the rounded end of the bulb.

The exhaust tube is then welded to the bulb at this point (Fig. 32), care being taken to maintain a free air passage so that later on the air may be pumped out through this tube.

The tubulated bulb is then placed over the completed mount, both being held in their proper relative positions (Fig. 33). Bunsen flames are applied at the neck of the bulb and both the bulb and mount are rotated slowly until the neck of the bulb is welded to the flare of the stem tube. The seal thus formed at the neck of the bulb must be absolutely air tight.

The exhaust tube is connected up to a vacuum pump and all air is exhausted from the lamp. At the same time that this is being done the lamp is inclosed in an oven which is heated to a high temperature. When the exhaust is complete, the lamp is sealed off, forming the tip of the lamp (Fig. 34).

After exhausting the base is put on (Fig. 35). One of the leading-in wires is brought down through and soldered to a cap at the end of the base. This cap is insulated from the shell by black glass. The other leading-in wire is soldered to the brass shell.

In the Mazda C lamp (Fig. 36), the bulb after being exhausted is filled with an inert gas, such as nitrogen. The presence of this

gas retards the evaporation of the filament and permits it to be operated at a much higher temperature thus producing more light.

In this lamp the filament is closely coiled into the form of a fine spiral spring. The purpose of this coiling is to prevent the rapid cooling of the filament by the circulation of gas within the bulb. The coiled filament is mounted on the anchors as shown in the figure.

THE MEASUREMENT OF CANDLEPOWER.

An effective study of illumination must take into consideration the methods of light measurement and the terms used. The general name photometer is given to the instrument used in measuring the luminous intensity of a light source. This intensity is expressed as candlepower and its value is measured in terms of the candle as a unit.

The value of this unit was originally defined as the horizontal luminous intensity of a sperm candle of certain specified construction, one-sixth of a pound in weight and burning at the rate of 129 grains per hour. This was known as the British Standard Candle.

The difficulties met with in its exact reproduction led the manufacturers of both gas and electric lamps to devise other practical comparison units, the pentane gas lamp and the incandescent electric lamp, each having a known value in terms of the standard candle.

In 1909 the United States, Great Britain and France adopted at the international conference, what is known as the International Candle as their unit.

The following values hold at the present time:

> 1 International Candle = 1 American Candle (United States) = 1 Pentane Candle (Great Britain) = 1 Pougie Decimale (France) = 1.11 Hefner Units (Germany). This unit is slightly less (1.6 per cent.) than the original British Candle formerly used in the United States.

Tested and seasoned incandescent lamps, rated in terms of the International Candle, are kept as arbitrary standards at the Bureau of Standards, Washington, and at other laboratories throughout the country.

There are many forms of photometers and in nearly all of them the eye of the observer determines when the illumination

thrown upon the screen of the instrument, by the light sources to be compared, is the same.

Since the measurement is a matter of comparison, the candlepower of one source in terms of the candlepower of the other, is found by the application of the law of the inverse square.

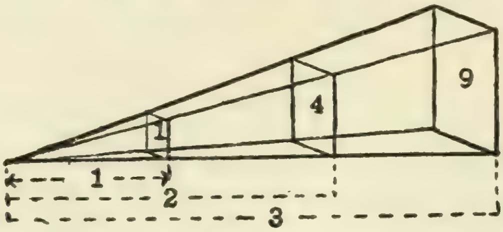


Fig. 37.—Law of the inverse square.

This law is dependent upon the fact that if a screen is set up at a distance of 1 ft. from a very small, or point source of light, the intensity of illumination upon that surface is four times as great as upon a surface of the same area 2 ft. away and nine times as great as upon a surface of the same area 3 ft. away. In other words the intensity of illumination is inversely as the square of the distance from the source of light.

PHOTOMETERS.

One of the earliest photometers was that devised by Count Rumford, an American whose name was formerly Benjamin Thompson. This is called the shadow or Rumford photometer. It consists simply of a base board, at one end of which there is an upright screen of white cardboard and at the other end an upright rod.

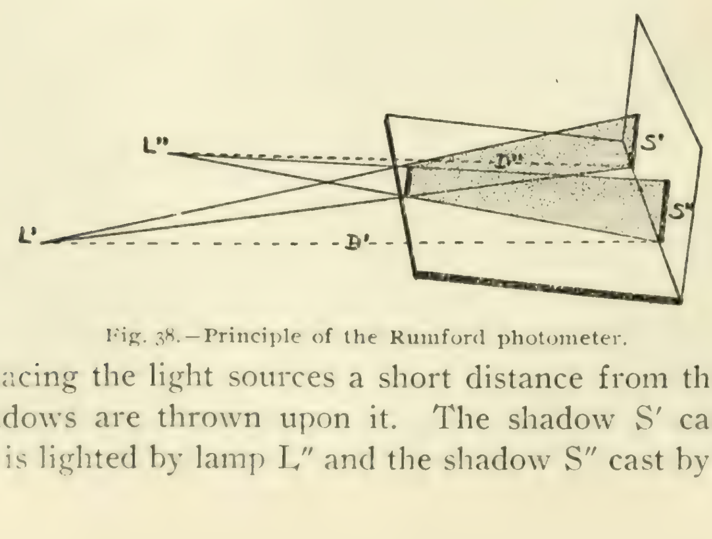


Fig. 38.—Principle of the Rumford photometer.

On placing the light sources a short distance from this screen, two shadows are thrown upon it. The shadow S′ cast by the lamp L′ is lighted by lamp L″ and the shadow S″ cast by the lamp

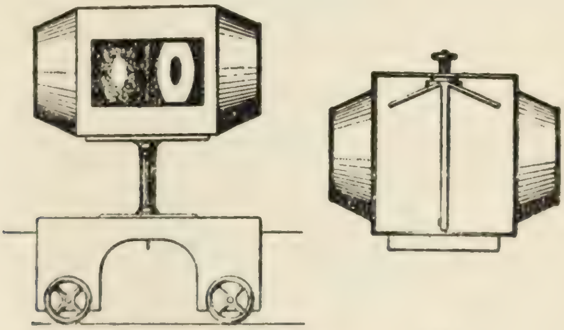
L″ is lighted by L′, hence the distances to be measured are D′, which is L′ — S″, and D″, which is L″ — S′. Then from the law of the inverse square the following holds:

Candlepower of L′ : Candlepower of L″ = $(D')^2 : (D'')^2$.

If, for example, L″ is a standard candle, D′ = 4 ft. and D″ = 2 ft., then

Candlepower of L′ : 1 = 16 : 4, or L′ = 16 ÷ 4 = 4 Candlepower.

The Bunsen, or grease spot photometer (Fig. 39) makes use of a white paper screen placed between two sources of light. A spot of grease or paraffin, with a well defined outline is placed in the middle of the screen.



(a) Fig. 39. (b)

(a) Bunsen photometer, front view, showing the spot out of balance, owing to the illumination of the disc being greater on the right than on the left.

(B) Bunsen photometer plan, showing disc-holder and inclined mirrors.

The spot increases the transparency of the screen to such an extent that a great part of the light falling upon it is transmitted. When the screen is in such a position between the light sources that equal amounts of light are transmitted from each source, the spot will become invisible because the amount of light transmitted from the source opposite the observer, added to the small amount reflected from the light source on the same side as the observer, will exactly equal the amount of light reflected by that part of the screen around the grease spot. When the position of the screen between the light sources is such that the spot disappears their distances from the screen are measured and the relative candlepower can be determined by applying the law of the inverse squares.

In order that the two sides of the screen may be seen at the same time, two small mirrors (Fig. 39 b.) are used. They are

placed vertically and make an equal angle with the screen, the angle being that required to bring the image of the spots to the eye. By having these two images near each other the position of equal illumination can be determined more accurately.

The distance of the sight box, containing the screen and mirrors, from the sources of light are usually measured by means of a scale fastened to the photometer bench or base of the instrument.

The distance between the lamps is usually fixed and the sight box is on a car that can be moved along the bench between them. By using a standard lamp of known candlepower the scale can be calibrated in candles instead of inches or centimeters and the readings made directly in candlepower.

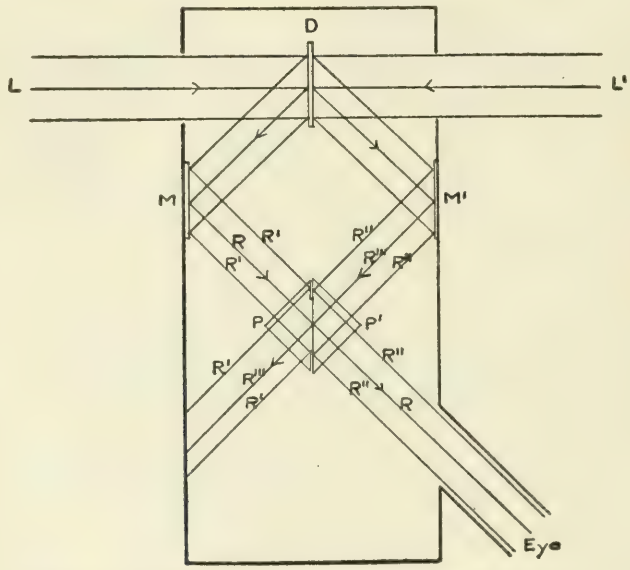


Fig. 40.—Principle of Lummer-Brodhun sight box.

A photometer screen or sight box that is largely used is the Lummer-Brodhun (Fig. 40). In this the spot box of the Bunsen photometer is replaced by a box containing two right angled prisms that are cemented together along a part of the hypothenuse faces while one of them is cut away along the remaining part.

The light from the standard lamp L strikes upon a white diffusing screen D from which it is sent to the mirror M and reflected perpendicularly to the face of the prism P into which it passes without change of direction.

The rays R which fall upon that part of the prism P that is in contact with the prism P′ pass through without a change of direc-

tion while the rays R′ which strike upon the part of the face of the prism P that has been cut back, are totally reflected, since they strike at an angle that exceeds the critical angle from glass to air and pass out the other face of the prism P.

The light coming from L′, the lamp to be compared, strikes upon the opposite face of D, falls upon M′, is reflected to P′ where the central rays pass through while the outer rays R″ are totally re-

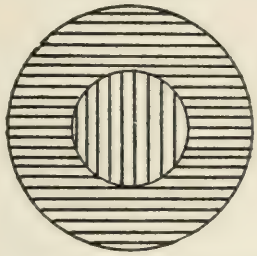


Fig. 41.—Lummer-Brodhun field.

flected parallel to R. The eye of the observer receiving these rays R and R″ will see a bright circle (Fig. 41) C surrounded by a darker ring, if the illumination from L is greater than that from L′, a dark circle surrounded by a brighter ring, if the illumination from L′ is greater than that from L and an evenly lighted surface if these illuminations are equal.

In taking a reading the sight box is moved until the spot and ring disappear when the reading of the distances is taken and the candlepower determined.

Photometers are used by the manufacturers of lamps to determine how they shall be classed as to candlepower and by purchasers to determine whether they meet the requirements of the conditions under which they are to be used.

RATING OF LAMPS.

Lamps are rated in either mean horizontal candlepower or mean spherical candlepower. By horizontal candlepower is meant the candlepower in any direction in a horizontal plane, around a lamp the axis of which is vertical.

The average of the horizontal candlepower in every direction is the mean horizontal candlepower. The incandescent gas mantle lamp and the incandescent electric tungsten lamp give nearly uniform horizontal candlepower so that a measurement of the candle-

power of these lamps in any horizontal direction is practically the same as a measurement of the mean horizontal candlepower.

With other forms of lamps this is not the case and a measurement is required in several directions to determine the most useful position for the lamp.

The average of the candlepower in all directions is called the mean spherical candlepower. In general, the mean spherical candlepower is not nearly as great as the mean horizontal candlepower, but the two values will usually bear a constant ratio to one another for lamps of the same design.

It is therefore usual to determine for lamps of each type in general use, the factor by which mean spherical candlepower can be computed from mean horizontal candlepower. This, called the reduction factor, is obtained by dividing the mean spherical candlepower by the mean horizontal candlepower, is less than unity and is expressed as a decimal. In one type of Mazda B lamp, for example, the reduction factor is 0.79.

CANDLEPOWER CURVES.

The most satisfactory record for the candlepower of a lamp is the candlepower curve. To make such a curve for any lamp choose some point on a sheet of paper to represent the position of the center of the lamp and draw radiating lines out from this point at whatever angles the readings are taken.

Lay off along these lines, to any suitable scale, distances from the center that will represent the candlepower in each direction.

The closed curve made by joining the ends of the lines will be the candlepower curve for the lamp, in whatever plane the readings are taken.

The mean horizontal candlepower curve will be a circle with the average of the lengths of all the lines drawn for its radius (Fig. 42).

This value can also be determined experimentally by a single reading if the lamp is rotated with a speed sufficiently high to give a steady illumination while the reading is being taken.

Similar curves can be made for the distribution given out by a lamp, in a vertical plane (Fig. 43).

There is much greater variation from the mean in these curves because of the shape of the lamp and the position of the filament.

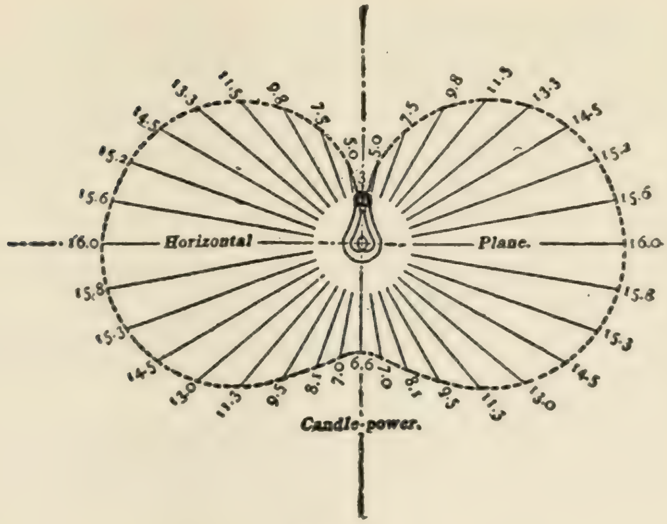


Fig. 43.

Curves of vertical distribution are useful since they show in which direction the light is the strongest and consequently in what position the lamp should be placed to give the best results.

SHADES AND GLOBES.

The distribution of light from lamps may be greatly modified by the use of shades and globes.

Shades are used for the purpose of giving a definite direction to the light rays. They are made with inner surfaces that reflect a large portion of the light and are made of such a shape as to concentrate the light over a small area (Fig. 44) or distribute it over a greater surface as may be required (Fig. 45).

Globes are generally used to modify the distribution from lamps having high intrinsic brightness. The great brilliancy of modern sources of light makes it necessary that the eyes of the user should be shielded from their direct rays. If one accidentally looks at the sun for an instant that part of the retina on which the rays fall becomes blind for a time. A similar result is the effect of looking at an arc light or at a high power gas or electric incandescent lamp.

No protection was needed against the light from the candle, open gas flame or oil lamp because their intrinsic brightness was low, from three to eight candles per square inch, but with the Welsbach mantle, which is from twenty to fifty, the carbon filament lamp in which it is nearly five hundred and the Mazda lamp,

in which it is from eight hundred to a thousand, some form of protection for the eyes against the direct rays is a necessity.

The most effective material for the purpose is one that prevents the source of light being seen through it and one that gives an equal glow over the entire surface of the globe, without absorbing too much light.

Great advances have been made in securing these results recently. Such globes substitute a large and pleasing source of light for the brilliant and trying glare of the uncovered source and are called diffusing globes.

Globes with prismatic ribs on both the inner and outer surfaces are also used to control and direct the distribution of light and are efficient for such purposes.

THE MEASUREMENT OF ILLUMINATION.

It sometimes happens that instead of wishing to measure the candlepower of a source of light we wish to measure the illumination that the light throws on a given surface. This is made in terms of the unit of illumination which is called the foot-candle, that is the illumination that falls upon a surface having an area of 1 sq. ft., every point of which is at a distance of 1 ft. from a 1 candlepower source of light. This means that the surface is part of the surface of a sphere having a radius of 1 ft.

Light may be said to flow from its source and this flow is called a luminous flux. The unit is called the lumen and is the flux that flows from a 1 candlepower point source, and it gives to an area of 1 sq. ft., at a distance of 1 ft. from the source an illumination of 1 foot-candle.

If this area is bounded by a circle on the surface of a sphere the flux is in conical form. The flux through any section, perpendicular to the axis of the cone is 1 lumen, whatever the distance of the section from the source of light (Fig. 46).

The illumination on these cross sections, however, diminishes as the square of the distance from the source increases, that is, the flux is constant, the illumination is variable.

Since the area of a sphere 1 ft. in radius is $4\pi = 12.57$ sq. ft., a 1 candlepower source of light gives out a flux of 12.57 lumens. The flux given out by any source of light having uniform intensity in all directions is computed by multiplying the candlepower of

the source by 12.57, that is, mean spherical candlepower times 12.57 equals total light flux emitted in lumens. The illumination on any surface equals the candlepower divided by the square of the distance, *i. e.* Footcandles $= \frac{\text{Candlepower}}{(\text{Distance})^2}$.

Several instruments have been devised for the measurement of illumination among them being the Sharp-Millar and the Macbeth Illuminometers. These instruments are both portable, make use of the Lummer-Brodhun sight box and contain a standard lamp. When used for the measurement of illumination the Sharp-Millar Illuminometer is as shown in Fig. 47.

The illumination falls upon a translucent glass plate *P* at the end of the rotating tube extending out from the end of the box. A mirror *M* at the elbow of the tube reflects the illumination into a Lummer-Prodhun screen within the box. This illumination is compared with that furnished by a standard lamp within the box by means of the eye piece *E*. The position of the standard lamp is controlled by the knob *K* and its voltage by the resistance coils *R*. The position of the lamp is read from a scale in the side of the box.

The cross section of the Macbeth Illuminometer (Fig. 48) shows the eye piece *F*, the Lummer-Brodhun prism *L-B*, the standard lamp *S* and the direction *I* from which the illumination enters the box. The car which carries the standard lamp is fixed to the end of a rod that is calibrated and serves to measure the distance of the lamp from the prism. The illumination can be read from a test plate placed in any desired position or from any illuminated surface.

A very convenient piece of apparatus for the measurement of illumination is the foot-candle meter. This device is in the form of a small box that contains a battery, lamp, rheostat and voltmeter. The lamp is at one end of the box, the top of which is made of an opaque card having a row of small holes punched in it lengthwise of the box. These holes are covered by translucent paper and are lighted from below by the meter lamp, each receiving an amount of light that depends upon its distance from the lamp. When the lamp is at its standard voltage the light received at each hole is calibrated in foot-candles.

On exposure of the upper surface of the meter to light in a room a balance is obtained between the light from the room and the light from the meter lamp and the reading of that hole that seems to disappear is taken as the number of foot-candles of illumination at the place of the test.

INTERIOR ILLUMINATION.

Illumination may be divided into two general classes, interior and outdoor lighting, and each requires its own particular method of treatment, kind of lamp and amount of illumination.

The final decision regarding the success of any kind of lighting rests with the eyes. If the eyes are supplied with sufficient light for their purposes, are enabled to do their work without conscious effort and come away from its use for a considerable time without a feeling of weariness and strain, the lighting is a success. If these results are not secured it may be considered a failure.

Experience shows that the amount of illumination required for different purposes varies greatly and is dependent on many conditions.

Tables have been made of the illumination required for different uses and the following is part of a report from a committee on the Artificial Lighting of Schools in Great Britain.

Room	Foot-candles
Drawing room	5 to 9
Class room	3 to 5
Study	3 to 5
Bench work	3 to 5
Laboratory	3 to 5
Office	3 to 4
Assembly room	2 to 3
Cloak room	0.8 to 1
Corridor	0.8 to 1

The above illumination is that given upon the working surfaces such as table tops and desks.

Interior lighting may be classified as either localized or general. The units used in localized lighting are of small candlepower and low intensity while the lamps are either partly or wholly portable. Table and piano lamps are of this class. In fact it may be said to include all lamps that are used for special purposes. These lamps have the advantage of bringing the light to just the place where it is wanted and the disadvantage that if they are used

without a general illumination also they leave the room dark except the small portion they illuminate, a condition that is especially trying to the eyes.

Experience teaches that the human eye should have thrown upon its retina no large areas of shadows or large extra bright areas. Eye strain results whenever a spot of light is thrown on a book or other work while other nearby objects remain in comparative shadow.

How the appliances that are used so as to give poor illumination may be arranged so as to give good illumination may be shown by a concrete example. It is sometimes the misfortune of a student to be provided with a room having a single incandescent lamp and a bare study table placed in the middle of the room. Not infrequently the lamp is located over the table in such a position that spectral glare is produced on the calendared surface of the text book being studied. The illuminant itself is in the range of vision and causes eye strain, while the region beyond the table within the range of vision is in relative darkness, conditions which are all objectionable.

The first remedy that suggests itself to the student is to purchase an eye shade. This improves the conditions by cutting off the direct rays from the light but results in his looking at a brightly illuminated page surrounded by the equivalent of a deep shadow.

Much better illumination will be secured by moving the table from the middle of the room to a position near the corner of the room having a wall in front and to the right side. The direct light from the lamp falls upon the surface of the table and book coming from over the left shoulder of the reader while the diffuse light reflected from the walls serves to prevent the formation of too dense shadows.

In general lighting the units are larger, the lamps are stationary and are so placed near the ceiling or walls that the light is evenly distributed over the room.

KINDS OF DISTRIBUTION IN ILLUMINATION.

The distribution of illumination in general lighting may be either direct, indirect or semi-indirect. The direct method is the older and simpler form. It makes use of all types of lamps, with or without globes or shades, in which the light passes directly to

the surface to be lighted without being reflected from either the walls or ceiling. It is a desirable system for some requirements but it produces intense shadows and is apt to be trying to the eyes on account of the direct rays from the lamp striking them.

Quite opposed to this is the indirect method in which the light from the lamp strikes upon a mirror and is reflected to the ceiling from which it is diffused into the room. Fig. 49 shows an untouched night photograph, indirect lighting.

No direct light from the lamp can strike the eye since the lamps are concealed either by the suspended bowl or by the cove in the side wall in which the lamps are placed in what is called the cove system of illuminating large rooms and auditoriums.

No distinctly intense shadows are cast in this system and the diffused light is pleasing to the eye.

A pleasing modification of the indirect lamp is made by the use of the luminous bowl (Fig. 50).

To secure this effect a cup shaped piece of white opal glass is set into a hole in the bottom of the reflector. This permits a small percentage of the light to pass through and illuminate the bowl evenly giving it an artistic effect.

If the opaque bowl and mirrors are replaced by a translucent bowl opening upward which reflects a part of the light against the ceiling and transmits a part of it downward into the room, the system is called semi-indirect.

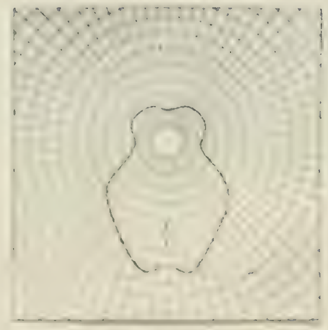
This reflects less light to the ceiling than is reflected in the indirect system and sends a certain portion of it directly into the lower part of the room.

By a study of what is required for the lighting of any room data can be found either for the installation of some one of these systems or for such a combination of the different systems as will provide suitable illumination.

SPECIAL FIXTURES.

There are many special kinds of fixtures, such as lamps and distributors, that are designed to meet the requirements of various occupations.

In the lighting of factories there is need both for the lighting of the individual machines, such as lathes and planers, and for a general diffused illumination in the room that shall approximate the distribution of daylight.



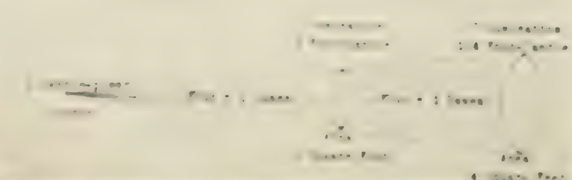



Fig. 42.—Candlepower curve in horizontal plane.
Fig. [illegible].—Measurement of illumination.
Fig. [illegible].—An indirect lighting unit.

Fig. 44.—Curve of concentrating shade.
Fig. 48.—Cross section of Macbeth illuminometer.
Fig. [illegible].—An untouched night photograph, indirect lighting.

Fig. 45.—Curve of distributing shade.
Fig. 47.—Sharpe-Millar photometer.
Fig. 51.—Factory "Reflex."

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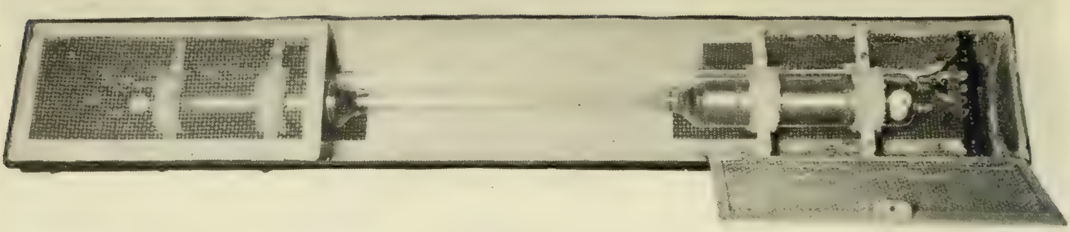

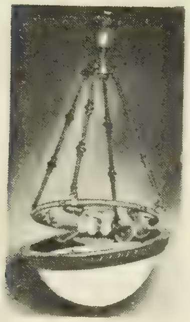

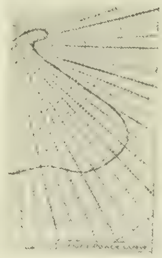

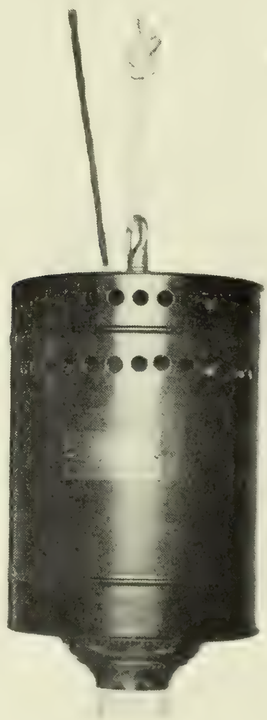

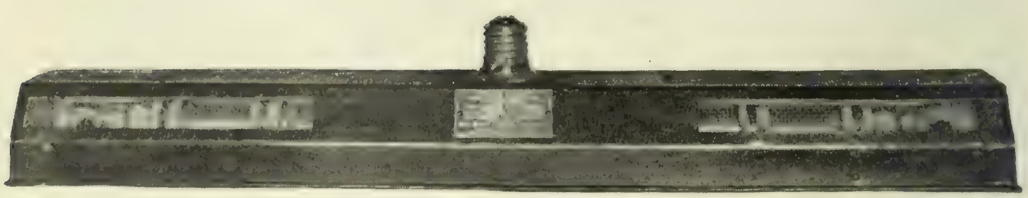

Fig. 52.—Distribution curve of "Reflex."

Fig. 53.—Type F. Cooper-Hewitt.

Fig. 54.—Combination fixture (Wellsbach).

Fig. 55.—Details of daylight lamp.

Fig. 56a. Upper Section Fixture for CO_2 Tube

Fig. 56b.—CO_2 Tube Fixture.

Fig. 56c.—Details CO_2 Tube.

Fig. 58.—Bowl frosted lamp and all frosted lamp.

This is met in gas illumination by the use of a reflex mantle lamp with a clear glass globe surrounded by a metallic shade of such a shape as to throw the greater part of the light downward within a cone of 120° or 60° from vertically below the lamp (Fig. 51).

The upper part of the metal shade is perforated with holes which allow sufficient light to pass through into the upper part of the room to provide the general illumination.

The distribution curve (Fig. 52) shows that with a lamp of 160 spherical candlepower, this shade throws 300 candlepower vertically below the lamp and a maximum of 415 candlepower at an angle of 45° from the vertical.

Another lamp that is well adapted to factory lighting is the Cooper-Hewitt mercury vapor lamp (Fig. 53). This lamp differs in two respects from those previously described.

The light is produced by the passage of an electric current through a vapor making it luminous and the color is lacking in red rays.

Since the luminous vapor is contained in a tube from 2 to 4 ft. long, the distribution of the light is good with an absence of sharp shadows and glare.

The bluish green color of the light tends to give greater acuity of vision, that is, it enables the eye to distinguish fine details with ease, while the color is not trying to the eyes.

The spectrum of the light being deficient in many of the wave lengths makes this light unsuitable for interior lighting on account of the changes made in color effects. It is, however, a light of high actinic quality and is well adapted to the lighting of objects for photography.

Each kind of current requires its own type of lamp, the one illustrated being an alternating current, 800 candlepower lamp.

Another luminous vapor lamp and one which produces light of a daylight quality is the Moore tube. In this lamp the quality of the light is determined by the kind of gas introduced into the tube.

It frequently happens that a room is both wired for electricity and piped for gas, making it desirable to furnish either a fixture for each or a combination fixture that is provided with both gas and electric lamps.

The illustration (Fig. 54) shows one solution of the problem of providing a satisfactory combination fixture.

THE EFFECT OF COLOR IN THE SOURCE OF LIGHT.

The need for light of daylight quality, or that having in it all the colors of sunlight is especially imperative whenever colors are to be matched or whenever it is necessary to know what the color of a piece of goods is by daylight. A daylight lamp has been devised which uses a Mazda lamp as the source of light. Fig. 55).

This lamp is inclosed within an opaque shade which directs the light downward through a specially prepared glass disk, the composition of which is such that the light which passes through it is of daylight quality.

The illustration shows how the lamp may be opened, the upper part containing the lamp and the lower part the prepared glass.

A simple experiment that shows the need of proper color in light is easily made by winding a strip of cloth that has been soaked in salt water around the tip of a Bunsen burner and lighting the gas.

The light given by this arrangement will be the monochromatic yellow light of the sodium flame. By contrasting the appearance of ribbons, flowers, or pictures having a variety of colors in them, seen under this light, with their appearance as seen by daylight, it will be evident that no color except yellow looks right under this yellow flame.

The reason for the change in the appearance of colored objects when seen under a light of a single color is that no color can be reflected from the surface of any object unless that color is included in the incident light.

Colored dress goods that are selected by daylight because they look well together may form combinations of color that do not harmonize at all well in a room lighted by lamps that differ greatly from daylight in their quality.

Not only is it necessary that practically all their wave lengths should be present in order that colors may appear normal, but there should be a fairly uniform distribution of intensity through the range of the spectrum.

These conditions are fulfilled in the light from the carbon dioxide Moore tube. The spectrum of this type of color-matching

lamp shows that it can be used as a standard light by which to judge colors.

While not every wave length is present the eye is unable to detect color difference in objects when placed in this light and daylight. The detail view of this color-matching lamp (Figs. 56, a, b, c,) shows that the light source is of considerable area thus preventing too sharply defined shadows.

It is of interest to note that the maximum luminous effect of colors on the eye occurs at nearly the same wave length as the maximum distribution of energy in sunlight (Fig. 57). The curve

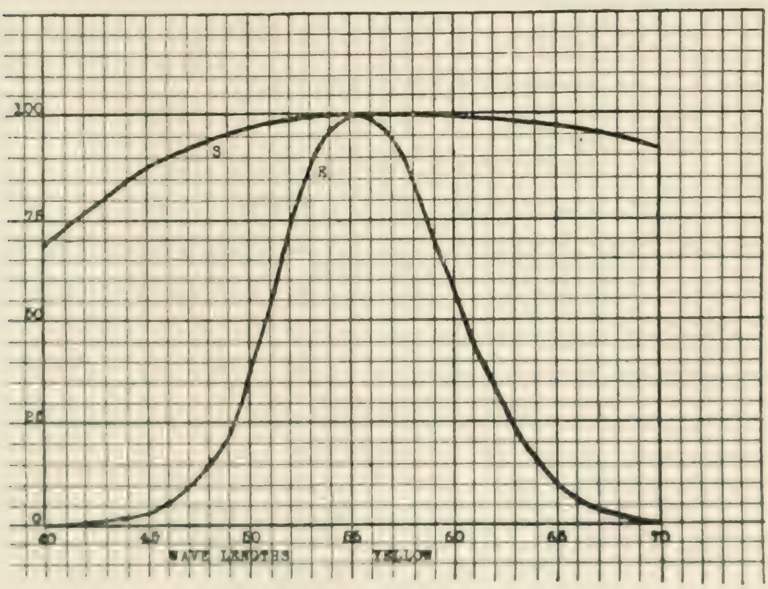

Fig. 57.—Curves of sunlight distribution and sensibility of the eye.

S is that of sunlight distribution and *E* shows the response of the normal eye to color sensation.

The fact that the greatest sensibility of the average human eye is to the wave lengths that produce yellow in the spectrum makes the introduction of a certain amount of yellow light of value in the illumination of interiors by producing a light that is more agreeable to the eye.

This quality exists to a large extent in the light from the candle and kerosene lamp. It is being secured in incandescent electric

lamps by the use of colored glass in the manufacture of lamp bulbs.

THE COST OF ILLUMINATION.

Whatever may be the source of illumination, we only make use of the light produced while the thing we pay for is the candle, oil, gas or electricity consumed.

In the use of each of these there is a certain definite relation between the quantity used and the light produced. The part of the light that is available in illumination depends both upon the method of distributing the light and the kind of accessories, such as shades, globes and reflectors that are used.

If the amount of light produced and the cost of producing it are alone considered the candle is ten times as expensive as the kerosene lamp, the open flame gas lamp costs nearly five times as much as the mantle lamp and the carbon incandescent electric lamp about three times as much as the best form of tungsten lamp.

In computing the cost of gas lighting the candlepower per cubic foot of gas must be known. This is determined by the composition of the gas and can be controlled by the manufacturer.

Gas that will give 20 candlepower when burning at the rate of 5 cu. ft. per hour in an open-flame burner is called 20 candle gas and will give about 4 candles for each cubic foot of gas consumed per hour in such a burner.

If it is assumed that the cost of gas is one dollar per thousand cubic feet it is seen that one dollar will pay for 4000 candle hours.

If such a lamp is burned for four hours each night the cost of running it for one month will be sixty cents.

If, instead of using the open-flame lamp, a mantle lamp, the C. E. Z., for example, is used, the amount of gas burned will be reduced to about 3 cu. ft. per hour, making the cost for one month 36 cents and instead of getting a 20-candlepower lamp. one of 90 candlepower is obtained.

The cost of electric lighting depends upon the cost of electric energy expressed in kilowatt-hours.

Incandescent lamps are rated in watts and are called 25-watt, 40-watt, 60-watt, etc. This means that the product of the electrical pressure in volts at the terminals of the lamp, multiplied

by the current in amperes passing through the lamp, is equal to 25, 40 or 60, since watts = volts $\times$ amperes.

If a 40-watt lamp is on a 110-volt circuit the current passing through the lamp is $40 \div 110 = 0.35$ of an ampere. To run such a lamp for five hours will require 200 watt-hours and the cost of running it five hours per night will be two cents, if the cost of electric energy is 10 cents per kilowatt-hour.

This lamp will give at least one candle per watt, that is, 40 candles.

The total cost of running either gas or electric lights will include the first cost of the lamps and the renewal of the parts burned out.

Since the purpose of illumination is to provide good lighting for the eyes it should be so used as to be neither unpleasant nor harmful to them.

For this reason the use of clear glass electric bulbs, and brilliant kerosene or gas lamps should be avoided.

There are two distinct objections to these uncovered lamps, first they produce glare spots from any reflecting surface such as glossy book paper and second, light from such lamps shining directly into the eyes renders them less sensitive to other light and makes it necessary to provide more brilliant illumination for the entire room.

The surface of the paper on which this monograph is printed is reasonably free from gloss and is an example of the kind of surface that has little glare and is restful to the eyes.

The objection to clear glass lamps is overcome by using frosted bulbs for incandescent electric lamps (Fig. 58) and shades or globes for the others.

The thing to be avoided in the use of shades is a too great concentration of light on the surface of a desk or other place where work is being done, while too little is thrown into other parts of the room.

Working under this intense light tires the eye, makes it less sensitive and, if persisted in, becomes permanently harmful.

EXTERIOR ILLUMINATION.

Street lighting presents an entirely different problem from interior illumination. The units used must be larger and the di-

tribution curves of these units must show a maximum distribution but little below the horizontal.

The lamps used are of many types. The open flat-flame gas lamp has given place to the mantle lamp and this is being replaced in some places by the multiple mantle lamp of high candlepower for which gas under high pressure is provided.

Open carbon arc lamps and inclosed carbon arcs have been used. These have been largely replaced by the magnetite and flaming arc lamps and these again are finding a formidable rival in the high candlepower gas filled Mazda lamps.

To the lighting furnished by these lamps must be added the general illumination furnished by the special lighting of signs and the flood lighting of buildings.

The proper consideration of this phase of illumination would require more space than can be given to it in this monograph and for this reason it will not be considered further.

THE ERA OF ILLUMINATION.

The attempt has been made in this monograph to tell a part of the story of the development of illuminants and of the methods used in the measurement of illumination.

Since prehistoric time man has been eager for more brilliant lights. These have been secured by the perfecting of the incandescent gas mantles and of the incandescent and arc electric lamps.

The end of the nineteenth and the beginning of the twentieth centuries have seen such a marvelous application of scientific investigation to the solution of the problems involved that it may well be called the era of illumination.

The solution of these problems has called for the birth of a new profession, that of the illuminating engineer, while co-operation between these engineers has resulted in the formation of the Illuminating Engineering Society.

As the function of the illuminating engineer is to scientifically establish the requirements for good illumination and to standardize the methods of producing this result, so it is the function of the Illuminating Engineering Society to further all efforts made to secure good lighting and to distribute such information as it may have in its possession by means of its lectures, transactions and other publications.

REPORT OF THE COMMITTEE ON PROGRESS.*

INTRODUCTION.

"Ye are all the children of light, and the children of the day:
We are not of the night or of darkness."

I Thess. 5:5.

In view of the magnitude of the recent war and the enormous drain of both men and materials it seems rather surprising that during the reconstruction period which is now upon us the economic disturbances should have been so relatively few and progress and development should have continued in the broad realm of illumination. It is true that in some directions, such as street lighting for instance, and particularly abroad, fuel and labor conditions have been such that there is not even yet a return to normal pre-war lighting in many cities and hence developments have been few. Reference will be made to some innovations in street lighting in this country, but the main effort seems to be more along the lines of reestablishing the programs of extensions and replacements which in so many cases were suddenly interrupted by the international crisis.

The renewal of nominal relations with alien countries, and the possibility of importing their technical periodicals has brought information of a number of developments in those lands, particularly, in Germany and quite a few references to progress in that country have been included.

One of the movements temporarily delayed by the war was the International Commission on Illumination, and it is encouraging to be able to report[1] that a resumption of the work of this body is planned for next year.

* Report prepared for presentation before the Fourteenth Annual Convention of the Illuminating Engineering Society, Oct. 4 to 7, Cleveland, Ohio. Subject to final revision for the TRANSACTIONS.

The papers and discussions included in our own TRANSACTIONS are not, in general, referred to in this Report, it being taken for granted that members keep themselves advised of the contents of the TRANSACTIONS.

[1] *Gas Jour.*, June 29, 1920, p. 834.

Referring to the early days of gas lighting at Cambridge,[2] Dr. Chas. W. Eliot has stated that he was personally responsible for the introduction of gas into the college buildings. As a student rooming in Holworthy Hall in the early fifties, he prevailed upon the Corporation, in the face of much opposition to allow the gas company to install piping in this building.

The increase in the use of electricity[3] for purposes of illumination may be judged by data obtained from central stations throughout the United States which show a growth in residential lighting customers from 3,434,900 in 1915 to 6,517,600 in 1920 and of commercial lighting customers from 1,085,900 in 1915 to 1,675,900 in 1920.

An example of appreciation[4] of the importance of the Illuminating Engineering Society as a factor in connection with accident prevention occurred in an exhibit under the auspices of the National Safety Council and the Safety Institute of America shown in conjunction with the annual Congress of the National Safety Council. A model office and a model drafting room were exhibited, having indirect lighting installations, and a shop in actual operation provided with three types of lighting, poor, medium and ideal, which could be flashed on and off alternately.

It is reported[5] that the use of artificial light for increasing the efficiency of laying hens has been so satisfactory that a large number of poultry breeders are now using this means for increasing production. In some parts of the Middle West poultry dealers state that the egg supply during the past year from what was the off-season exceeded the regular supply during the regular laying season. The customary procedure has been as follows: beginning about the 15th of October, lights are turned on in the chicken houses at 3:30 A. M. and the chickens are immediately fed. This order is followed until about the 15th of February when the lights are turned on at 4 A. M. and a month later the use of artificial light is discontinued. The amount of light per square foot varies, but one watt per 50 sq. ft. (4.65 sq. m.) of floor surface seems to be a good average. This practice differs somewhat from

[2] *Gas Ind.*, Mar., 1920, p. 83.

[3] *Elec. Wld.*, July 24, 1920, p. 161

[4] *Elec. Rev.* (U. S.), Sept. 6, 1919, p. 391.

[5] *Elec. Rec.*, July, 1920, p. 52.

that reported by a western Canadian college experiment station[6] where a study was made of twelve pens of 25-single-comb white leghorn pullets. Six pens were given artificial light and the remainder maintained under ordinary daylight conditions. The experiments were carried on from November 15th to April 15th and the light was turned on at 7 in the morning until daylight, and again turned on at dusk and turned off at 10:30 P. M. The pullets in the lighted pens were not given their evening feed until after 7 o'clock. The results were 157 dozen more eggs from the lighted than from the unlighted pens. The cost per dozen in the lighted pens was 21.19 cents as against 33.64 cents from the unlighted pens.

This opportunity is taken for thanking those who have furnished data and the publishers whose periodicals have been consulted.

Respectfully submitted,

FRANCIS E. CADY, *Chairman;*
OSCAR H. FOGG,
W. B. LANCASTER,
F. R. MISTERSKY,
W. E. SAUNDERS.

[6] *Elec. News* (Can.), Dec. 1, 1919, p. 30.

INDEX.

GAS.

Introduction.—Confronted by continually rising costs of material, particularly gas oil, by unprecedented increases in the cost of labor, and difficulty in obtaining funds for improvements, the gas industry is on the verge of revolutionary changes, and this is particularly true in England. For years gas companies have been under the most stringent regulations regarding the quality of the gas supplied. The Government requirements for benzol and toluol during the war made it necessary to remove or modify many of these restrictions, and, as a result, the movement to allow a wider latitude has gained considerable momentum. A bill before Parliament to change the basis of charging for gas and to allow the gas companies to fix the quality of their output has met with very favorable reception. Whether this will result in an increase in the use of gas for lighting purposes remains to be seen.

It is estimated[7] that the total gas consumption in Great Britain is approximately 240,000 million cu. ft. per year, and that of this amount 5 per cent. is used in flat-flame burners. The substitution of enough incandescent burners to give the same amount of illumination would mean a reduction in the coal needed to produce the gas from 1,000,000 tons a year to 170,000 tons, or even better. In the United States it has been stated[8] that 30 per cent. of the gas sold to-day is used for illumination purposes and an unpublished survey indicates that as in the case of Great Britain, open-flame burners account for only 5 per cent. of the gas sold for illumination.

Among the effects produced by the war in Germany[9] has been an increase in the use of gas, and a decrease in the use of petroleum for lighting purposes.

Manufacture.—A new illuminating gas has been reported[10] which is a modified acetylene. It is produced by adding wood alcohol and sodium bicarbonate to the usual calcium carbide and water. It is claimed that no heat is evolved during the reaction

[7] *Gas Jour.*, May 25, 1920, p. 428.
[8] *Gas Industry*, Jan. 5, 1920, p. 5.
[9] *Am. Gas. Eng. Jour.*, Dec. 20, 1919, p. 577.
[10] *Pop. Mech.*, May, 1920, p. 738.

and the spent solution leaves no residue of salts in the production chamber. The candlepower is said to be about the same as acetylene.

Burners.—No striking developments in gas burners for illuminating purposes have been announced during the past year. Further work on small units to replace flat-flame burners has been done in England. A new mantle burner of this type, apparently similar to one developed in this country and noted in last year's Report has been described.[11] The mantle is of the inverted type and is supplied fixed to the fire-clay nozzle, which in itself forms the burner ring. The nozzle has been so designed and shaped that the flame is evenly spread out. The bunsen tube is only two inches (5.1 cm.) long and conical in shape, the enlarged part of its base forming the mixture chamber. Air is admitted through four equally spaced apertures in a plate, fitted into the base of the tube, and in one piece with the screw for connecting the burner to the gas pipe. The gas is admitted through the center of the plate. The burner is intended to replace those of the flat-flame type in halls, corridors, lavatories, cellars, et cetera. A test of three of them using a gas of about 475 B. t. u. gross and at about 3 inches (7.6 cm.) pressure showed an average consumption of 1.10 cu. ft. per candlepower. It is claimed that the burner is simple, strong, with every part interchangeable, and that it can be used with a considerable range in gas quality.

The big differences in the characteristics of the gas furnished by various gas undertakings in England which may follow as a result of changes in the heat unit legislation has made it desirable to have mantle burners which may be used under as many different conditions as possible.[12] A new one designed to meet this need may be used with any one of a series of interchangeable nozzles fitted with mantles appropriate to the quality of gas supplied. The regenerative principle formerly applied to flame-gas burners to increase their efficiency has been utilized for the upright incandescent-mantle type.[13] Strongly pre-heated air is supplied to a bunsen tube through the use of an auxiliary glass globe

[11] *Gas Jour.*, May 25, 1920, p. 428.
[12] *Gas Jour.*, Feb. 3, 1920, p. 246.
[13] *Zeit. f. Beleuch.*, Feb. 15, 1920, p. 27.

in addition to the usual chimney. Tests have indicated a considerable improvement in the specific consumption.

A step in the direction of protecting those who still find it desirable or necessary to use flat-flame burners[14] is to be found in a new enriching apparatus for local application. By the use of benzol in a proper container a gas which has low illuminating power can be supplied with enough hydrocarbons to raise the candlepower to a satisfactory point. It is claimed that the economy in gas consumption compensates for the cost of the benzol used.

The government demands for benzol during the war, and the removal of candlepower requirements, in order to permit gas companies to furnish it, have emphasized the importance of a series of tests, the results of which have been published in France.[15] These tests, extending over a period of thirty years, indicate among many other effects, that benzol of itself represents 65 per cent. of the illuminating power of gas, while it accounts for only 7.2 per cent. of the heating value. Under the term "benzol" are included all hydrocarbons of the aromatic series from benzene to cymene.

Experiments on the relative efficiency of inverted and upright mantles have confirmed[16] an explanation which has been current for some time. The experiments showed that the cause for the increased efficiency of inverted burners over the upright is the pre-heating in the case of the former of the air and gas mixture by the hot products of combustion.

The work of the Research Sub-Committee of the Gas Investigation Committee of the British Institution of Gas Engineers has been continued[17] during the past year and a third report issued which deals with the effect of inerts on the efficiency of coal gas at ordinary pressures used for lighting with upright incandescent mantles. The experiments show that the reduction in attainable thermal efficiency and illuminating power when certain inerts are present in quantity (even though heat units be supplied at an equal rate) is in many cases over estimated. The tests were

[14] *Gas Jour.*, Jan. 6, 1920, p. 27.
[15] *Gas Jour.*, Aug. 19, 1919, p. 392.
[16] *Gas Jour.*, July 8, 1919, p. 77.
[17] *Gas Jour.*, June 8, 1920, p. 563.

made with straight coal gas of high, medium and low calorific values, the latter two having been produced by the dilution of the high grade gas by air in one series, by carbon dioxide in another, and by nitrogen in a third. The result with air indicated that it may be added to straight coal gas to the extent of 20 to 30 per cent. of the mixture without reducing in the slightest degree the illuminating power and thermal efficiency attainable by the consumer (with the upright incandescent mantle) if heat units are supplied at equivalent rates. For nitrogen a similar value is 24.6 per cent. and for carbon dioxide 10.5 per cent. When both nitrogen and carbon dioxide are present their effect is additive. It is stated[18] that "where nitrogen or carbon dioxide is added to a straight coal gas there is a reduction of theoretical flame temperature which might be expected to reduce the attainable illuminating power and thermal efficiency; but in practice such factors as flame shape and structure assume so much importance that only when the quantity of inerts becomes large, or when a specially arranged series of mixtures is under test, can the falling off in illuminating power and efficiency be definitely associated with the lowering of theoretical flame temperature. For smaller quantities of inerts and for gas compositions in general, any such effect is masked by other influences."

Calorific Standards.—In accordance with a request made in 1917 by the British Board of Trade, the Fuel Research Board of the Department of Scientific and Industrial Research has issued a report[19] for the years 1918 and 1919 covering recommendations regarding gas standards. They include some revolutionary changes, the most radical of which is one that the consumer be charged on a basis of the number of B. t. u. supplied him, taking 100,000 as a unit, the gas company to declare the calorific value of the gas it intends to deliver, and to undertake to adjust, and if need be, to replace gratis, the burners in consumers appliances so that the gas delivered can be burned with safety and efficiency. In London two large gas companies supply gas differing in quality by 110 B. t. u. and they have recently been successful in obtaining authority to continue this condition.[20] This has been presented as evidence in support of the contention that a fixed calorific stand-

[18] *Gas Jour.*, June 8, 1920, p. 507.
[19] *Gas Jour.*, Apr. 27, 1920, p. 180.
[20] *Gas Age*, June 25, 1920, p. 540.

ard is merely a fetish and that the consumer will readily adapt himself to any quality within reason.

A joint committee of the Societé Technique and the Professional Syndicate, two leading organizations of the gas industry of France, has recommended[21] to the authorities the substitution of a calorific for the illuminating standard for gas. 528 B. t. u. per cu. ft. is suggested as a maximum standard. In the fourth edition of the Bureau of Standards Circular No. 32, "Standards for Gas Service," a value somewhere between 525 B. t. u. and 585 B. t. u. is proposed as being in most cases the best average heating value standard.

The New Jersey Gas Association is in favor of lowering,[22] and will ask the Board of Public Utilities Commissioners to lower the standard of heating value in the state to 500 B. t. u. in view of the constantly increasing cost of gas oil, and of the results of research which show the possibility of making up the difference in B. t. u. by obtaining greater efficiency from the lower B. t. u. gas. An effort is being made[23] in Baltimore to have the heating standard reduced from 550 to 500 B. t. u. In Philadelphia an appeal was made[24] for the elimination of the candlepower standard and the substitution of the B. t. u. standard. This appeal was subsequently granted.[25] In Pennsylvania, the candlepower standard is in effect only in Philadelphia, and elsewhere, only two large cities, New York and Detroit, have a candlepower standard.[26] The Public Service Commission of Indiana has established[27] a new heating unit of 570 B. t. u. per cu. ft. of artificial gas. The quality may vary between a maximum of 600 and a minimum of 540, but the monthly average must be 570 B. t. u. In Kansas the prevailing[28] rate is 550 B. t. u. per cu. ft. In California[29] new rules for standards of gas service as prepared by the Railroad Commission went into effect on September 1, 1919. 570 B. t. u. is the required standard.

[21] *Gas Jour.*, Mar. 16, 1920, p. 614.
[22] *Gas Record*, June 9, 1920, p. 34.
[23] *Gas Age*, June 25, 1920, p. 550.
[24] *Gas Age*, June 25, 1920, p. 552.
[25] *Am. Gas Eng. Jour.*, July 17, 1920, p. 52.
[26] *Gas Age*, Nov. 1, 1919, p. 378.
[27] *Am. Gas Eng. Jour.*, May 8, 1920, p. 374.
[28] *Am. Gas Eng. Jour.*, Nov. 8, 1920, p. 452.
[29] *Gas Age*, Oct. 1, 1919, p. 288.

ELECTRIC INCANDESCENT LAMPS.

As in the case of gas there have been few striking innovations in the character or design of electric incandescent lamps in the past year. Improvements in manufacture have continued, but they have been more in the direction of mechanical perfection and in the uniformity of product than in changes in the content and characteristics. Considerable attention has been given to the lamp developed for use in moving picture projection and this will be referred to under the heading, "Lamps for Projection Purposes," as will also a lamp developed for use in searchlights.

Manufacture.—As was to be expected, the use of carbon-filament lamps continues to show a decrease.[30] They amounted in 1919 to only 7 per cent. of the total number of incandescent lamps sold. The use of gas-filled lamps shows a greater percentage increase than that of the vacuum-type. This may be due in part to the fact that five times as many of the latter were purchased. The average candlepower of all lamps again shows an increase, being nine times that of all lamps sold in 1907. The mean efficiency has also increased slightly.

In a study of the influence of various substances on the light absorbed by the film coating the inner surface of the lamp bulb,[31] (ordinarily termed "blackening"), it has been found that chlorine is not suitable for preventing blackening of the bulb. Chlorine does not attack tungsten below 200° C. At higher temperatures it forms WCl_6, which dissociates again, thus the blackening disappears when the lamp burns, but the effect is only temporary. When the chlorine pressure is too low, the bulb wall is not hot enough to re-evaporate the WCl_6, while at higher pressures, the chlorine may corrode the filament. Various experiments using NaCl showed that it is not decomposed, but volatilizes as such. By the aid of NaCl and CaF_2, the life period, during which the candlepower remained within 80 per cent. of its initial value, was prolonged between two and three times. (It should be noted that neither NaCl or CaF_2 is used to prevent bulb blackening in general factory practice in this country.)

During the fiscal year ending July first, the U. S. government[32] purchased over 5 million incandescent lamps. It is reported from

[30] Report of Lamp Committee, N. E. L. A., May, 19[illegible].
[31] *Proc. K. Akad.*, Amsterdam, 21, 9, p. 1078, 1919.
[32] *Sci. Abs.*, "A," Sept. 30, 1919, p. [illegible]; "B," Sept. 30, 1919, p. [illegible].

Prague[33] that a large incandescent lamp factory is to be established in that city to meet the needs of Bohemia, the succession states and the export trade.

Types.—A 100-watt, gas-filled tungsten lamp in the 220- to 250-volt class has been developed[34] and the relatively fine filament employed, together with that used in the 50-watt white bulb lamp show a measure of progress in the direction of low wattages for gas-filled units which was not regarded possible a few years ago. In England,[35] a 40-watt lamp for 100- to 130 volts and a 60-watt for 200 to 260 volts, both gas-filled and having ring-shaped filaments, have been announced. The mill-type of rugged filament lamp described in last year's report has been worked up into a satisfactory unit and laboratory tests indicate a strength of about five times that of the ordinary vacuum tungsten lamp, and when new, about three-fourths of the strength of the old carbon-filament unit. The necessity of protecting the eyes from glare when the high-brightness, gas-filled lamps are used in open reflectors has made it necessary[36] to use a more strongly diffusing device than mere frosting, and a finish known as "bowl-enameling" has been brought out for this purpose. It can be readily cleaned, and since the inner surface is reflecting, the effect of dirt on the exterior is not as great as in the case of frosted lamps, since less light is transmitted. The enamel is durable, will not chip off, is not affected by acid fumes, and does not discolor during the life of the lamp. By feathering the periphery of the enameling a sharp "cut-off" edge is avoided.

The success of the 50-watt white bulb lamp has led[37] to the development of 100-watt and 200-watt sizes. These are similar to the 50-watt in appearance, but are not tipless. A new outfit has been designed for Christmas tree lighting service.[38] It is of the multiple type and twenty lamps are used in a string and operated from a small transformer. Thus, the failure of one lamp no longer throws out the rest. This outfit uses a new bulb, cone-shaped and tipless, and colored with an evenly diffusing coloring

[33] *Sci. Amer.*, Oct. 11, 1919, p. 361.
Elec. Rev. (Lond.), Apr. 30, 1919, p. 555.

[34] Report of Lamp Committee, N. E. L. A., May, 1920.

[35] *Elec. Times*, July 8, 1920, p. 36.

[36] *Elec. Rev.* (U. S.), Apr. 10, 1920, p. 625.

[37] *Elec. Merch.*, May, 1920, p. 265.

[38] Report of Lamp Committee, N. E. L. A., May, 1920.

matter which has been developed especially for Christmas tree lighting in general. The lamps are of the 14-volt size, and may be used interchangeably with the old round bulbs for this purpose. A special lamp has been designed[39] for switchboard service. It has a tubular bulb and is rated at 15 volts, 12 c. p., 15 watts. A decided novelty in incandescent lamps is one designed to serve the double purpose[40] of providing light and an outlet to which to attach household appliances. The bulb is tubular and based at both ends and the leading-in wires are of the size and carrying capacity of those used in an ordinary 500-watt lamp. These wires continue through the lamp from base to base and the lamp filament is tapped off from them. The leading-in wires are formed into an expanded loop and are given a quarter twist to provide clearance for the filament anchors. Regular Edison bases are used and a threaded and insulated receptacle is permanently attached to the free end. It has been objected[41] to this arrangement that it is necessary to have the filament lighted when an appliance is attached, a condition, in general, uneconomical in the daytime. The value of the lighted lamp as an indicator that current is flowing has been presented[42] to meet this objection, and, as another possibility, the addition of a switch to cut out the lamp.

Properties.—A Swedish engineer has investigated the effect of surrounding temperature on the candlepower of incandescent lamps. Several lamps were run at temperatures of 200° C. and 20° C., and some, cooled by a brine-circulating device, were run at approximately 3° C. In the case of those run at 200° C. it was found that after some hours operation the luminous intensity had fallen off considerably, while in the case of those run at 20° C. and 3° C. there was no appreciable diminution after the same period of burning. His explanation was that at high temperatures the glass of the bulbs becomes sufficiently porous to permit air to seep through. The same explanation was presented for the deterioration of lamps used in large numbers close together as in advertising signs. Tests have been made[44] on the

[39] *Elec. Wld.*, Jan. 17, 1920, p. [illegible].
[40] *Elec. Wld.*, May 8, 1920, p. 1107.
[41] *Elec. Wld.*, May 29, 1920, p. [illegible].
[42] *Elec. Wld.*, July 10, 1920, p. [illegible].
[43] *L'Industrie Élec.*, Oct. 10, 1919.
[44] *Elektroindustrie*, Mar. 15, 1920.

ignition possibilities of electric glow lamps and it was found that a lamp can be broken in the midst of cold combustible material such as powder without igniting it. With a 32 c. p. lamp, cotton impregnated with rubber when put in contact with the bulb ignited in two minutes, black velvet in six minutes, a double layer of cotton cloth in two minutes. On fine powder, ecrosite and powdered pyroxiline no effect was noted. But ecrosite in thick layers melted and the powder gradually lost its sulphur, without igniting, however.

The cooling effect of leading-in wires on filament temperature and other properties of tungsten incandescent lamps[45] has again been studied in connection with the subject of electron emission for lamps having very short filaments, where the effect is very much magnified. The investigation is very similar to one covering the same subject for long filaments and reported to this Society in 1911.[46] During the course of the investigation, a redetermination was made of the temperature characteristics of the central or heated part of the filament. The results are given in the form of data from which may be computed the proper filament length and size to give a certain voltage drop and electron emission.

Maintenance.—A novel solution of the problem of eliminating breakage and theft of lamps in a mine was found[47] in the change from a 230-volt system to a 57½-volt system, using 60-volt lamps. The wiring was found adequate for the higher current and the 230-volt transformers previously used were easily adapted to the new system by the addition of balance coils giving a five-wire, 57½-volt layout.

The process of standardizing voltages to 110, 115 and 120 is progressing[48] and nearly 79 per cent. of all lamps sold last year were in one of these three classes, as against 75 per cent. the year before and 45 per cent. in 1913. It is remarkable that Japan has succeeded in establishing 100 volts as the standard pressure for incandescent lamps. Austria has been studying the question for the past three years and the Elektrotechnische Verein of Vienna

Tech. Rev., June 22, 1920, p. 546.

[45] *Jour. of the Inst. of Elec. Eng.*, Jan., 1920, p. 107.

[46] TRANS. I. E. S., 6, p. 238, 1911.

[47] *Elec. Wld.*, Jan. 17, 1920, p. 168.

[48] Report of Lamp Committee, N. E. L. A., May, 1920.

has proposed[49] a plan providing for 110, 220 and 440 as standard voltages in direct current circuits, and a number of values of voltage and frequency for alternating current circuits. In Switzerland, the Swiss Elektrotechnische Verein and the Verband Schweizen Elektrizitätswerke have agreed[50] upon 110, 220 and 440 for direct current and 125, 220 or 350 for alternating current supply systems.

In Japan,[51] government standard specifications for the purchase of vacuum tungsten incandescent lamps have been issued. They were prepared by a special committee appointed by the Japanese Illuminating Engineering Society and the Japanese Electrotechnical Commission and recommended to the Minister of Communications in charge of the supervision of electrical undertakings in general. Two classes of lamps are recognized in rating, one of a normal life of 1600 hours, the other of 1000 hours. This is in line with the Swiss standard specifications. Bulbs are to be marked with the class as above referred to, voltage, watts, normal candlepower, (the last when requested), the manufacturer's mark, and the purchaser's if desired. Measurement of the mean spherical candlepower by the Ulbricht sphere is recommended, but the mean horizontal candlepower with the proper reduction factor may be employed.

ARC LAMPS.

Little has been published on the development of arc lamps of the ordinary type such as those used in street lights. There have been some improvements[52] in the magnetite arc lamp. By using a flattened electrode interchangably with the former type of round electrode it has been found possible to readjust the 4-amp. lamp from 320 to 270 watts thus resulting in a greatly increased lamp capacity in the rectifier and transformer equipment. An increase in the life per trim from 175-200 hours to 250-300 hours has also resulted. The life of the electrode has been lengthened by compounding it under extremely great pressures, thus packing more material in a given space. An electrode 7/16 by 11/16 by 8 in. (1.11 by 1.75 by 20.3 cm.) long will give a life equal to that of the former 5/8 by 8 in. (1.59 by 20.3 cm.) round long life mix

[49] *Elek. u. Masch.*, Feb. 29, 1920, p. 91.
[50] *Elec. Times*, July 9, 1920, p. 41.
[51] *Ill. Eng.*, Oct., 1919, p. 281.
[52] Report of Lamp Committee, N. E. L. A., May, 1920.

electrode, with an increase of efficiency of about 50 per cent. Improvements in the methods of manufacture have obviated oxidation and other troubles in the upper electrode.

Tungsten Arc.—The tungsten arc lamp, the use of which seems to be growing in England is now made in sizes from thirty candlepower to four thousand candlepower, the last being a new development.[53] Various improvements have been made in these lamps since their introduction four years ago. Among these may be mentioned the replacement of the thick filament made of tungsten and refractory oxides as an ionizer by a tungsten wire filament wound into a small spiral at one end, with the ionizing tube slipped over the straight portion. This has greatly lengthened the life. Higher candlepower lamps were made possible by the use of this new ionizer and also by the use of larger globules of tungsten, the latter forming the positive electrodes. Another development was the use of two positive electrodes, one a smaller and the other a larger globule, the lamp being started with the smaller and the arc subsequently transferred to the larger. The life of the tungsten arc lamp is limited by the following factors: the derangement of the ionizer; the gradual curvature of the plate electrode used in lamps of five hundred candlepower and over; the flattening of the globule; and the blackening of the bulb. The last has been remedied by the use of a glass cup of a particular size and shape which is welded to the inside of the bulb over the arc. The convection currents of hot gases from the arc rise into the centre of the cup and descend down the side of it forming a deposit on the walls of the cup, but leaving the bulb wall perfectly clean in the case of the high-wattage lamps and nearly so for the one-hundred candlepower lamps. It is supposed that the volatilization of the electrodes is checked by keeping them surrounded by an atmosphere saturated with tungsten vapor.

A new tungsten arc lamp with a fixed focus principle has a hemispherical positive electrode with its convex side opposed to the ionizer. The flat side presents a perfectly uniform disk of light, 1 cm. (0.4 in.) in diameter. It has already been found useful as a standard in pyrometry. Another recent improvement has made possible a minimum arc voltage of 15 instead of 45.

[53] *Elec. Rev.* (Lond.), Dec. 5, 1919, p. 724.
Elec. Rev. (Lond.), Jan. 2, 1920, p. 9.

The 1000 c. p. lamp with two positive electrodes takes 7 amperes at the start, 3 amperes on the first arc and 8 amperes when in full operation. The intrinsic brilliancy of the electrode is given as 16,000 candles per sq. in. for the 500 c. p. lamp, and 12,000 candles per sq. in. for the 100 c. p., but the latter can be run up to 60,000, at which brilliancy the globule is practically molten.

The effort to approximate a point source of light still continues.[54]. With this object in view an arc lamp has been developed which has a cored carbon rod of the ordinary type for the positive electrode and its luminous crater forms the source of light. The non-luminous electrode is a metallic ring, water-cooled, surrounding and presenting its inner edge towards the crater. A magnetic field is employed to cause the arc between the inner edge and the crater to rotate at from 500 to 3,000 r. p. m. The action is too rapid to be distinguishable and the effect is a highly incandescent spot surrounded by a bluish halo. As the carbon electrode burns away, it is automatically moved forward by a regulating device controlled by the thermal expansion of a metal strip, and independent of the arc current and voltage. A lamp designed for the purpose of making luminous effects visible has been made by using an ordinary arc lamp with iron-cored carbons in connection with a long vessel, the thin outer walls of which are made of quartz or uviol glass, to act as a filter. The vessel is divided into two compartments by a thick wall of blue uviol glass, one being filled with a 20 per cent. aqueous solution of copper sulphate and the other with a 1 : 10000 aqueous solution of nitrosodimethylaniline. The lamp is enclosed and a condensing lens is placed between the source and the filament. A chimney in the box causes a draft preventing the deposit of carbon particles from the arc. The lamp can be utilized for microscopic observations on luminescence.

Vapor.—The Moore tube gaseous conductor lamp has been developed[55] for 220-volt circuits, without the use of any auxiliary starting device. Some of the disadvantages of the mercury vapor lamp[56] have been overcome in a new design which has for its basic principle the lighting of the arc under conditions of high internal pressure. This is accomplished by the addition of an

[54] *Rev. Gen. d'Elec.*, Apr. 10, 1920, p. 508.
[55] *Elec. Wld.*, Apr. 3, 1920, p. 802.
[56] *Rev. Gen. d'Elec.*, Dec. 6, 1919, p. 815.

auxiliary chamber containing argon, helium, neon, or other inert gas at a pressure of roughly 70 cm. (27.4 in.) of mercury. A fine tungsten filament runs through this auxiliary chamber and when heated by passing a current through it, causes the gas to expand and to break the mercury thread in the adjoining tube, thus starting the arc. It is claimed that the time required to reach a steady state is reduced to almost nothing, that the starting of the lamp is automatic, and that the operative pressure being higher, there is an increase in brightness and more energy is radiated in the visible and ultra-violet ends of the spectrum making possible the adaptation of the lamp to certain optical requirements. Another new lamp of similar type for use on alternating-current circuits is under development. A different type of alternating-current mercury-vapor lamp developed in France[57] consists of an illuminating tube of quartz with reservoirs at the ends containing a very small amount of mercury, (1 cu. cm. for a 2 kilowatt lamp), the electrodes being connected to the mercury. The lamp contains an atmosphere of rare gas, preferably neon, at a pressure of 1 cm. of mercury. It is mounted across the terminals of the secondary of the transformer whose primary circuit contains self-induction. On closing the circuit the inert gas becomes luminous, and the voltage drop at the terminals is of the order of 2 volts per cm. arc length. The mercury is rapidly vaporized and the terminal voltage drop goes down to 0.5 volts per cm. arc length. The spectra of the emitted light then contains only mercury rays. This is a period of luminescence in the mercury vapor. The quantity of mercury being small, the pressure continues to increase rapidly until stability is reached. The terminal voltage drop becomes 50 volts per cm. The arc takes the form of a fine thread and reaches its final stable condition after about seven minutes' burning. The dimensions of all parts must be very exact. In a given case, the tube was 40 cm. (15.7 in.) long, took 2 kilowatts and operated on a 130/3000 transformer. The current was 1 ampere, and the voltage across the terminals 2,250 volts, with a power factor of approximately 0.7.

An improvement in the auxiliary lamp apparatus used with ordinary mercury vapor lamps for alternating-current supply[58] lies in the replacement of the choke coils formerly employed by a

[57] *Comptes Rendus*, Feb. 23, 1920, p. 458.

[58] *Elec. Wld.*, May 15, 1920, p. 1169.

positive low-resistance, unit, thereby raising the power factor from 52 per cent. to 85 per cent., and the allowable voltage variation from 12 per cent. to 25 per cent. The candlepower of the tube is greater by 12 per cent.

The use of a cadmium-vapor arc[59] in a quartz tube to take advantage of a spectrum whose red lines have sufficient intensity to make it desirable for a monochromatic source of light, has been going on for some years, but the use of pure cadmium introduces difficulties, the principle one being the tendency of the metal to adhere to the quartz wall. This interfered with the employment of the lamp in practice until it was found that the addition of zirconium eliminated the trouble. Another method has been developed and tried out which consists in the use of gallium instead of zirconium. It was found that in distilling cadmium from an alloy of cadmium and gallium at a pressure of 0.001 mm. of mercury, the minute quantity of gallium carried through was sufficient to prevent the adhesion between the cadmium and the quartz walls of the lamp. A lamp of this type has been constructed with a total volume of approximately 10 cu. cm., having tungsten electrodes passing through quartz capillaries with lead seals, operating on 7 amperes with 25 volts drop across the terminals. It is claimed that under these conditions, a practically pure cadmium spectrum of great brilliancy is obtained, apparently equal to that which would be obtained were cadmium alone present. Gallium has only a few lines in the visible spectrum and the two at 0.640μ and 0.641μ are weak, leaving the pure red line of cadmium at 0.644μ as the only source in the lamp of any intensity in this region.

Characteristics.—Additional data have been obtained[60] on the potential current curves obtained with rod electrodes. It is claimed the results can be employed for any arcs working under corresponding conditions as regards electrode heating. The following table gives the values found for a and b in the formula $ei = ai + b$ where e is the potential and i the current:

[59] *Phil. Mag.*, Mar., 1920, p. 353.
Phil. Mag., June, 1920, p. 678.

[60] *Phys. Zeit.*, Sept. 1, 1919, p. 393.
Sci. Abs., "A," Dec. 30, 1919, p. 567.

	a.	b.
Mercury arc, low pressure	55.6	4
Mercury arc, moderate pressure	95.2	24
Mercury arc, high pressure	125.3	46
Carbon arc, length 2.5 cm. (1 in.)	90	89
Carbon arc, length 0.4 cm. (0.16 in.)	56.8	22
Salted carbon arc (CaF_2), length 2.5 cm. (1 in.)	42	36
Salted carbon arc (CaF_2), length 0.15 cm. (0.06 in.)	28	10

Measurements have been made[61] of the color (spectral distribution) of some of the high intensity arc lamps, such as those used in searchlights. Two methods were employed; first, color matching by the method of rotary dispersion using a comparison source of known spectral character, and second, by using a spectral photometer of the polarization type. By the first method, a 45-volt, 75-ampere searchlight lamp of the regular army, Sperry type was found to match in color very closely noon sunlight in Washington as given by Abbot, *i. e.*, approximately that of a black body at 6000° K. In the experiments by the second method, an auxiliary photometer was used to determine the time at which the intensity of the arc was the same in the required direction as its average intensity, and the spectrophotometer readings at the various wave-lengths were made only at such times. The results showed a preponderance of radiation in the blue as was to be expected. This was shown to be due to the spectra of the rare earth oxides in the cores of the carbons, which in combination give a practically continuous spectrum. Experiments have been made[62] on metallic arcs which tend to support the assumption that the constancy of the temperature of the crater in the case of carbon electrodes, is explained by the assumption that the temperature observed is that of the boiling point of carbon and is independent of the current. The value, 4200° K, for this point agrees with observations by others. With arcs of silver, copper, iron, and nickel, after a certain current was reached, the brightness and temperature of the anode did not change with further increase of current. The tungsten arc proved to be practically constant at 4150 to 4250° K. for all current densities.

LAMPS FOR PROJECTION PURPOSES.

A novel portable hand lamp produced in Germany[63] is sup-

[61] *Phys. Rev.*, Aug., 1919, p. 184.

[62] *Archives des Sciences Naturelles Geneve*, 1919, p. 48. *Elec. Rev.* (Lond.), Sept. 19, 1919, p. 373.

[63] *Elec. Rev.* (Lond.), Oct. 31, 1919, p. 573.

ported on a trunnion so that it can be tipped through 90°. It is supplied with current from a battery which in a position at rest carries its liquid, sulphuric acid, in a production chamber so that the plates are not immersed. The latter are of lead, super-oxide and zinc. The lead plates must be charged and the cell approximates 2.5 volts. When the lamp is being used, it is tilted back so that the liquid covers the plates. When discharged, the lead plates are replaced with charged plates. They give 500 hours burning with one charge and can be charged from 100 to 150 times. The claim is made that the combination is cheaper to run than a lamp supplied by dry cells, or ordinary accumulators. The idea of eliminating the battery in hand lamps which came into some prominence during the war is still being considered.[64] A lamp of this type has been developed in which the current used is furnished as in some previous cases by manual operation of a small dynamo. The generator consists of a multipolar magnet which rotates around a fixed induction coil housed in the lamp case. An outside lever actuated by a gripping motion causes the necessary rotation. Numerous arrangements have been devised and are still being worked out to light the needle and record of talking machines. A typical instance[65] may be found in a new outfit consisting of a 4.2-volt dry-cell-battery concealed in the interior of the case, a socket, reflector, lamp, and spring switch to be mounted vertically on the inside of the case, or, on flush-type machines, horizontally.

Signalling.—As a result of the blockade during the war there was a dearth of petroleum in Germany and the defective purification of oil obtained from Gallicia caused great trouble in railway signal lamps. The impure oil gave a dim light and frequently caused a carbon deposit on the chimney. A remedy was found when the wicks were soaked for five hours in a 20 per cent. solution of potassium nitrate and then dried. This greatly increased the illumination. A report has been made[66] of experiments carried on during the war to study the use of ultra-violet light in connection with fluorescent screens for stern lights and signalling purposes between a ship and others following it. A right angle carbon arc with a current up to 25 amperes and a vertical arc with

[64] *Pop. Sci. Monthly*, Nov., 1919.
[65] *Elec. Rev.*, May, 1920, p. 202.
[66] *Phys. Rev.*, Aug., 1919, p. 188.

a current up to 15 amperes were employed as test sources in conjunction with various glasses and solutions used as filters to cut out the visible radiation. The receiver was a short-focus, quartz lens forming an image on a fluorescent screen observed by a low-power ocular from the opposite side. The range was 654 meters (0.4 mile) which was extended in effect by rotating sectors. All tests were made by night. As a condition of sensitiveness it was found necessary to cut out all extraneous illumination from the observers eyes and this was done by using a close-fitting shade and a thin piece of "purple-ultra" glass between the objective and the screen. The results showed that it was possible to observe a clearly visible fluorescent image when the source was nearly or quite invisible to the unaided eye, but it was difficult to reach definite conclusions as to the absolute invisibility of such a source and even with the best filters the source was visible when near it. Furthermore, the question proved to be complicated by fluorescence in the eye itself.

In an analogous manner[67] the decay of phosphorescence of zinc sulphide under the action of infra-red radiations was employed by the army for invisible signalling. The transmitter was a concave mirror with an incandescent lamp at the focus and means for exposing and shutting off the light. The receiver was a continuous band coated with zinc sulphide driven by clockwork, the zinc sulphide having been excited by radiations, from an incandescent lamp filtered through an ammoniacal solution of copper sulphate. The range employed was up to 14 Km.

For years the London police have carried as a part of their night equipment, a bull's-eye oil lamp. Commencing January 29, 1920,[68] these were replaced as fast as possible by electric lanterns, deriving their current from small storage cells re-charged every day. The lanterns are compact with two flat sides and a hook for the belt. As a result of the congestion[69] of traffic at certain street intersections in Boston, the traffic policeman have been provided with electric lights placed on the peak of their campaign hats and also on either shoulder. The light on the hat is red, while those on the shoulders are white.

Searchlights.—Special incandescent lamps to replace arcs in the

[67] *La Tech. Moderne*, Feb., 1920, p. 86.
[68] *Elec. Rev.* (Lond.), Feb. 6, 1920, p. 180.
[69] *Illus. Wld.*, Jan., 1920, p. 765.

18-inch (45.7 cm.) arc searchlight are available. They operate at 100 amp. on 11 volts, use a 30-inch (76 cm.) mirror and have a life from one hundred to two hundred hours. Lamps of much higher voltage are being experimented with. A mirror of deposited silver with a backing of copper and cement for searchlight use is also being perfected. Among the incandescent lamp searchlights used in the navy, is one called "the 12-inch (30.5 cm.) incandescent lamp" largely used on all classes of naval vessels for long-range daylight signalling in fair weather and for navigational use at night on small boats. Due to special adjustments and care required in service, it has not been as satisfactory as it might be and it has been suggested[70] that a new type be designed so that it cannot be incorrectly used. The lamp socket is to be permanently fixed in such a position that when a 150-watt, high-speed lamp bulb is placed in it, some part of the filament will be at the focal point. The use of a bayonet base will also help to avoid the use of lamps not especially designed for the purpose. It is suggested also that the number of sizes of searchlights fitted for low-power arc lamps be reduced.

Special lamps for lighthouse work have been developed abroad.[71] For such work the distribution of light must be such that the prisms most remote from the filament receive enough light and the form of filament considered best for the purpose is a combination in two planes crossing each other perpendicularly. A 30-amp., 80-volt lamp of this type has been brought out and a 50-amp. 80-volt lamp is under development. Both are gas-filled tungsten lamps and for the latter, a combination of argon and nitrogen has been found most satisfactory for the gas. Smaller lamps developed include a 2.5 amp., 220-volt lamp with parabolic reflector suitable for use on light ships and a 200 c. p. type with dioptic lens. The French department of lighthouses has departed[72] from the time honored Fresnel optical system in a lighthouse installation on the island of Galiton off the coast of Tunis. The reflector is parabolic, 2.25 m. (7.6 ft.) in diameter with a focal distance of 0.65 m. (2.1 ft.) It is made up of four sections of bronze specially gilded and burnished, and said to be the largest ever constructed. It is mounted on a support floating in mercury

[70] *Proc. A. I. E. E.*, Dec., 1919, p. 1369.
[71] *Ill. Eng.*, Oct., 1919, p. 298.
[72] *Comptes Rendus*, Sept. 8, 1919, p. 471.

permitting a complete revolution in 20 seconds. Laboratory tests gave a maximum power of about 202,000 candles. Aerial navigation in Great Britain is being carefully looked after[73] and an acetylene flare has been designed for guidance of night flying. It is in the shape of a truncated hexagonal prism and is provided with glass directing prisms to give a powerful vertical beam. A simple folding tripod enables the light to be placed anywhere in a field. It is reported[74] that high intensity searchlights of the Sperry type have been utilized in motion-picture production and German army searchlights have been used in that country for that purpose. A new portable unit[75] has been designed for highly localized light at distances not greater than 125 ft. (38 m.) from the lamp. It is claimed that by the use of a hammered glass reflector a smooth white light is obtained without glare. A 200-watt gas-filled tungsten lamp is employed and the reflector is spring-suspended in a one-piece cast iron housing closed by a wire-glass front. For small locomotives such as those used in industrial plants, logging camps, etc., a special headlight has been brought[76] out, using twelve-inch (20 cm.) mirror reflectors and either 100, 150 or 250-watt gas-filled concentrated filament incandescent lamps. A focusing device is made readily accessible.

Automobile Lamps.—Special attention has been given[77] to improvements in the uniformity of dimensions of headlight lamps. Various signal-lamp arrangements have appeared from time to time designed to enable a motorist to indicate to those following an intended turn to the right or to the left or a stop. A device of this kind[78] consists of two semaphore arms, one placed on either side of the wind shield, fitted, the one with a red light, the other with a green light, both arms and lamps being controlled by buttons on the steering wheel. The left-hand bull's eye projects a red light and the right-hand one a green light, following railroad and maritime practice. The stop signal is given by lowering both arms, a right turn by lowering the right arm only. The lamps light when the arm reaches a horizontal position. Another

[73] *Sci. Amer.*, Dec. 13, 1919, p. 586.
[74] *Sci. Amer.*, Jan. 17, 1920, p. 59.
[75] *Ry. Elec. Eng.*, Dec., 1919, p. 455.
[76] *Elec. Wld.*, Aug. 30, 1919, p. 499.
[77] *G. E. Rev.*, Jan., 1920, p. 67.
[78] *Elec. Rec.*, Sept., 1919, p. 147.

device[79] for this purpose is disk-shaped and mounted at the end of a supporting arm to be attached to the windshield. The centre has an arrow-shaped portion which can be rotated so as to bring into view any one of the words, "stop," "right" and "left." The whole is illuminated at night by means of a small lamp operated by the starting and lighting battery.

Using the fender as a support for auto headlights is not new, but a departure from custom is to be found[80] in a headlight made up with a cannon-like sleeve. The reflector and bulb are at the larger end and the smaller end is fitted into an opening in the front fender, somewhat back of the wheel and at such a point that the beam of light passes between the inner side of the wheel and the under edge of the front apron of the fender. The reflector and lamp are detachable and with a long connecting cord can be used as a portable lamp. Among the many attempts to avoid glare in auto headlights may be mentioned a lamp bulb partially coated with a permanent transluscent material, the coating covering that part of the bulb which ordinarily causes glare.[81] The base of the bulb is designed to fit any single or double-cut-out auto socket and is provided with a swivel collar permitting it to be adjusted to the no-glare position after it has been pushed home in the socket. An application of the artificial daylight idea has been made[82] in the case of the front glass in an auto headlight. Another unusual glass[83] is ribbed, has part of its surface made matte and carries a concave clear glass projecting portion in the centre. The ribs are said to be for the purpose of diffusing the light, the matte surface for deflecting it and the concave portion for projecting the light coming directly from the bulb.

Motion Picture Projection.—Considerable improvement has been made in the incandescent lamp equipment as used in motion-picture projection.[84] Difficulty resulting in a short life was experienced with the early types of lamps due to differences in the time taken up in expansions of the supports and the filaments. This trouble has been eliminated, as has also the tendency toward distortion of the filament which formerly resulted in lowered use-

[79] *Elec. Rev.*, July, 1920, p. 18.
[80] *Pop. Mech.*, May, 1920, p. 705.
[81] *Elec. Rev.*, May, 1920, p. 298.
[82] *Elec. Merch.*, Nov., 1919, p. 264.
[83] *Elec. Merch.*, Feb., 1920, p. 110.
[84] Report of Lamp Committee, May, 1920.

ful candlepower. In addition to the above, as a result of intensive study given to the subject, numerous minor improvements have been made in the auxiliary housing.

Miner's Lamps.—Work on lamps for use in mines[85] has been going on in Germany. The neon lamp has been adapted for this purpose and is said to have given very good results. The absence of high temperature in the immediate extinction of the light in the presence of even traces of air seems to eliminate any possibility of gas explosions due to lamp breakage. The current consumption is low. The question of admitting the use of acetylene lamps has been raised[86] in England on the basis of the need for more light, particularly in the case of rescue work.

STREET LIGHTING.

An impetus has been given to the subject of highway lighting[87] by the interest of the Good Roads Association, and that which has resulted as a by-product of national, state and local highway and good-road movements. Among the advantages of such lighting have been listed the following: (1) prevent collisions; (2) reveal dangerous curves; (3) reveal bad crossings and culverts; (4) show uneven places in road surface; (5) eliminate blinding headlights; (6) equivalent to policing; (7) facilitate interurban and interstate truck traffic; (8) assist in making repairs; (9) relieve the strain of night-driving; (10) decrease running time, (freight and pleasure); (11) illuminate guide-posts and road signs; (12) provide social benefit to residents as in a lighted town; (13) reveal pedestrians and moving objects.

Since the inauguration of the so-called "Path of Gold" on Market Street in San Francisco in 1916 there has been a steady growth in what has been designated "Intensive" lighting, as distinct from mere "White Way" lighting.[88] The distinction lies in a greatly increased illumination; relatively high lamp standards and four or five times initial installation costs and maintenance. Except for the additional aesthetic value of the decorative lamp standard, it might be regarded as general flood-lighting. A question having been raised regarding what seemed to be excessive

85 *Helios*, Apr. 18, 1920, p. 180.

86 *Elec.*, June 25, 1920, p. 699.

87 Report of the Lighting Sales Bureau, N. E. L. A., May, 1920.

88 *G. E. Rev.*, May, 1920, p. 362.

height for the so-called "intensive" lighting standards in Los Angeles, the following reasons were given[89] as an explanation:

1. The high power source is more out of the direct line of vision.
2. The general distribution is much better and the effect of high intrinsic brilliancy minimized.
3. The reflections of the lamps in the show windows are projected at a lower angle and come less into the line of vision and therefore interfere less with the window displays.
4. Horizontal shadows of street cars and other objects are foreshortened.
5. The high standards look much more dignified by day as well as by night, and, owing to the height of the mass, the sidewalks look less narrow than with the ordinary low standards with their clusters of globes 10 or 12 ft. (3.7 m.) above the sidewalks.
6. In intensive white way lighting it is desired to carry the light up to the sky-lines of the buildings with good illumination on the cornices, so that for this reason if no other the lamps should be placed 25 to 30 ft. (7.6 to 9.1 m.) above the sidewalk level.

In England,[90] the difficulty of getting arc light carbons during and since the war has done much to accelerate the conversion in street lighting from arcs to incandescents. Another contributing cause has been the excessive cost of labor in connection with trimming the arc lamps. In this country data have been compiled[91] on the relative performance of the old enclosed carbon arc lamp, many of which are still in use, and the modern incandescent-lamp street-lighting unit.

There has been a general tendency to again take up in various municipalities, the development of street lighting. Information on some installations will be found in the following record:

Oregon.—The city of Portland has during the last twelve months improved its street lighting system only by the addition of a very limited number of arc lamps.

California.—In San Francisco no notable installations have been made, due largely to lack of funds, in excess of those required to maintain the present lighting system. Gas lamps are slowly being replaced with electric lights. The form of unit installed is the pendant type suspended from a bracket attached to wooden pole lines. Series incandescent lamps ranging in

[89] *Jour. of Elec.*, Mar. 15, 1920, p. 238.

[90] *Elec.*, May 7, 1920, p. 811.

[91] *G. E. Rev.*, June, 1920, p. 511.

candlepower from 100 to 600 are used in banded refractors. The increased cost of labor and of fuel oil used in the generating of the gas have been given as two of the reasons for the change from gas to electricity. The initial installation of two hundred sixty-eight, 6.6 amp. luminous arc lamps for the "White Way" system[92] on Broadway, Los Angeles, has finally been completed.

Missouri.—Arrangements have been made to continue gas street lighting in St. Louis[93] where there are some 23,000 in use. On one of the avenues of the city[94] it has been proposed to increase the number of lights, using two mantles and a different style, thereby increasing the amount of light to three times. Replacement of electric lights by gas[95] has been ordered on the section bounded by Summit and Pleasant Avenues and the railroad tracks, while another order was passed to install five-light electric cluster lamps on Exchange Street. Fiftieth Street, Kansas City,[96] is to be the scene of a trial of a new street-lighting system. 400 c. p. lamps are to be placed on trolley-pole brackets, four to the block.

Illinois.—A very elaborate program[97] of improvements in street lighting was submitted to the voters of Chicago for approval, but a $15,000,000 bond issue was involved and the plan was lost by a small margin.

Michigan.—A year ago the city of Detroit[98] had in service over 7,000 of the 4-amp. magnetite luminous arc lamps using the flat electrodes, which permit of reducing the watts consumption from about 310 to 270. Ninety to ninety-two lamps are run on a circuit that formerly served seventy-five. During the year 730 lamps have been added and 394 of the old A. C. enclosed arcs have been replaced by the luminous arcs. Considerable improvements have been planned for the ensuing year.

Ohio.—The former street lighting equipment of Alliance,[99] consisting of one hundred eight arc lamps and one hundred eighteen 100 c. p. incandescent lamps having become inadequate and obsolete, arrangements have been made for a new system. There will be 529 lamps; those in the business district being of

[92] *Jour. of Elec.*, Feb. 15, 1920, p. 151.
[93] *Jour. of Elec.*, Feb. 15, 1920, p. 151.
[94] *Am. Gas Eng. Jour.*, Nov. 29, 1919, p. 528.
[95] *Pub. Works*, Apr. 17, 1920, p. 26.
[96] *Elec. Rev.* (U. S.), Apr. 17, 1920, p. 673.
[97] *Elec. Wld.*, Feb. 14, 1920, p. 399.
[98] *Elec. Wld.*, Sept. 13, 1919, p. 580.
[99] *Doherty News*, Mar., 1920, p. 30.

400 c. p.; those in the major part of the residence district 250 c. p.; and on the outlying streets 100 c. p. The system has been planned by a street-lighting engineer.

Kentucky.—A 6.6-amp. series incandescent lamp, A. C. system has replaced the former series multiple circuits for street lighting in Lexington.[100] Fifty-nine 1,000 c. p., two hundred sixty-eight 600-c. p., four hundred ninety-three 400-c. p., and one hundred twenty-eight 100-c. p., lamps have been installed. At Georgetown, arrangements have been completed for installing 250 gas-filled, tungsten street lamps of 600, 400 and 100 c. p. In addition there will be 60 boulevard lighting standards equipped with 600-c. p. lamps.

Pennsylvania.—Bethlehem has contracted for the installation[101] of an ornamental lighting system covering five miles of streets.

New Jersey.—As a result of a conference of an illuminating engineer and officials of the local lighting company,[102] the city of Trenton has provided plans for improvement in street lighting involving an entirely new layout. In the meantime,[103] the arc lamps in the centre of the city are to be replaced by 600-c.p., gas-filled tungsten lamps, and, in the outlying districts, three hundred sixty-six 400-c. p., lamps and two hundred fifty 100-c. p., units are to be installed.

New York.—The most striking innovation in street lighting during the past year is to be found[104] in a new installation at Saratoga Springs. As a summer resort and racing centre this city has a large population during four months of the year and a small one the rest of the time. A dual system of lighting on a single circuit has been designed to give adequate illumination for a fashionable summer resort when needed and an economical system suitable for a village at other times. It furthermore permits of the reduction of light after midnight when the high illumination has been on before that hour. Two lamps, a 1000-c. p. and a 250-c. p., are placed in each globe, and at the bottom of the standard is a box containing a relay which is operated by a current surge from the station caused by momentarily short-circuiting the feeders at

[100] *Elec. Rev.* (U. S.), Mar. [illegible], 1920, p. 471.
[101] *Elec. Wld.*, Jan. 10, 1920, p. 110.
[102] *Pub. Works*, Apr. 17, 1920, p. 26.
[103] *Elec. Rev.* (U. S.), Apr. 17, 1920, p. 671.
[104] *Elec. Rev.* (U. S.), Mar. 13, 1920, p. 436.

the generating station. The relay transfers connection from one lamp to the other; thus, the system can be changed from high to low c. p., or vice versa. One hundred and forty globe fixtures have been installed on Broadway, supplying two thousand c. p. each during the summer up to midnight, when five hundred are used. The latter will be the all-night lighting during the remaining months of the year. The standards are located opposite each other and spaced 135 ft. (41.1 m.) apart. The centre of the light source is 20 ft. (6.1 m.) from the ground. Sixty-nine standards light one mile of street. The residential extension of Broadway has been equipped for one mile with single globe fixtures, each containing 600-c. p., series incandescent lamps. The inauguration of the system was made the occasion of a big civic celebration. In New York City there has been an increase of only 758 in the number of lamps in service, the additional lamps being installed in sections where extensions in lighting were found to be absolutely necessary. On some of the principle thoroughfares the requirements of increased traffic and public improvements necessitated an increase in illumination which was obtained by readjusting the existing types of lamps. The installation of remote control switches for lighting and extinguishing electric lamps on the multiple distribution system was extended with satisfactory results. Progress has been made on the installation of a new street lighting system[105] in the extension of Melville Road, Rochester.

Connecticut.—A "White Way" has been established in Danbury, by the use of 90 single-light luminous arc lamps.[106]

Massachusetts.—The number of lamps in the city of Boston up to, and including May first, 1920, is as follows:

Magnetite arc lamps	800 c. p.	Series	5297	(including 255 "white way")
	500 c. p.	Multiple	26	
Incandescent	40 c. p.	Series	1836	
		Multiple	1447	
	60 c. p.	Series	730	
		Multiple	567	
	100 c. p.	Series	3	
		Multiple	14	
	200 c. p.	Series	10	
	500 c. p.	Multiple	11	
Gas open flame, fire alarm			144	
Single mantle gas			9704	

105 *Elec. Rev.* (U. S.), Dec. 6, 1919, p. 965.
106 *Doherty News*, Feb., 1920, p. 30.

England.—Last fall, the London Safety First Council adopted[107] a report submitted by the Sub-Committee on Street Lighting which emphasized the importance of uniform procedure in the Greater London area. The Commission recommended that this could best be obtained by compliance with the terms of the standard specifications on street lighting presented by a joint Committee of the London Illuminating Engineering Society and the various Institutes of Gas, Electricity and Municipal Engineering. They also recommended that a survey be made to determine classification of streets in the order of their importance in accordance with the specifications, and to ascertain whether the minimum illumination provided after carrying out the proposed post-war alterations in street lighting is equal to that which the specifications demand. It was urged that in making changes care should be taken to insure that there should be no sudden transitions from brightness to relative darkness, either in passing from a side street into a busy main street, or vice versa. High-pressure gas lighting[108] in certain sections of London has been resumed, involving 512 lamps of 500-c. p., 2,260 of 1,000-c. p., 352 of 1,500-c. p., and 14 of 3,000-c. p. The Hackney Borough Council has put up[109] about four hundred 300-watt, gas-filled tungsten lamps in prismatic bowl-refractor units.

At Hove, England, a new system of street lighting has been installed,[110] using overhead central span suspensions. This span suspension avoids the use of poles, but the necessary guy wires stretching from building to building constitute a return to outside wiring conditions similar to those which have been and are being eliminated in this country. In the 1919 Report of the Lighting Engineer of the city of Liverpool,[111] it is stated that the system of clock-work controllers for automatically lighting and extinguishing the gas street lamps which was inaugurated in 1908 has proved satisfactory and is being extended. At the beginning of the year, 7,522 gas lamps were lighted and at the close of the year this number had been increased to 11,106 out of a total of 19,974. The total length of roads equipped for lighting at the end of the year, irrespective of courts and passages, amounted to

[107] *Gas Jour.*, Aug. 19, 1919 p. 399.
[108] *Gas Jour.*, Nov. 19, 1919, p. 3[illegible].
[109] *Gas Jour.*, Mar. 23, 1920, p. 684.
[110] *Elec. Times*, Jan. 1, 1920, p. 13
[111] *Gas Jour.*, June 15, 1920, p. 739.

520 miles, (837 km.)—486 by incandescent gas, 8 by electricity, 3 by flat-flame burners, and 4 by oil. At Airdrie the arc and incandescent lamp street-lighting system[112] has been replaced by a high-pressure gas installation. The arc-lamp standards were remodeled for use with gas, as were the poles for carrying trolley wires, where arc lamp posts were not available. Twenty high-pressure inverted lamps of 1,500-c. p., are used and smaller units replace the incandescent lamps. All are automatically lighted by the pressure-wave system. At Ealing, arc lamps on center standards[113] are to be replaced in the Uxbridge Road district by 200-watt gas-filled tungsten lamps at the sides of the road, 400 ft. (122 m.) apart.

Greece.—Plans have been made[114] to light some fifty villages on the island of Syra.

India.—Arrangements have been made[115] at Sukkur, a town in the Sind Province, of India, for a power plant which will furnish current for street lighting, the steel poles and other fittings for which, have also been provided for.

China.—Of recent years[116] there has been a considerable development in the use of electricity in China, and this includes street lighting. In the Canton Province, the total number of electric lamps for all purposes is given as 300,000; in the Kiangsu Province, 900,000 lamps; in Oairen and neighborhood 65,000 lamps; at Antung, 16,000 lamps; at Yingkow, 15,000; at Port Arthur, 11,000; in Tsinan, Chifer and Tsining 6,000 to 9,000 each.

Japan.—With the advance[117] in Japan of illuminating engineering, as indicated by the formation of their Illuminating Engineering Society, it is surprising that in a city as large as Tokio there is, as last reported, no regular system of street lighting. Each property owner has to suspend a light from his door to illuminate the thoroughfare. As there are no regulations as to the character of the illuminant, candles, oil, gas, and electric lamps are used.

[112] *Gas Jour.*, Apr. 20, 1920, p. 150.
[113] *Elec. Rev.* (Lond.), Aug. 15, 1919, p. 206.
[114] *Elec. Rev.* (Lond.), Dec. 26, 1919, p. 816.
[115] *Elec. Rev.* (U. S.), Jan. 24, 1920, p. 138.
[116] *Elec. Times*, Sept. 18, 1919, p. 229.
[117] *Gas Jour.*, Dec. 9, 1919, p. 550.

OTHER EXTERIOR ILLUMINATION.

Floodlighting.—Floodlighting of buildings for spectacular purposes has been so common in this country that it is interesting to note that what is said[118] to have been the first occasion in Great Britain where floodlighting has been used for the special illumination of public buildings occurred at Glasgow, Scotland, at the time of the Peace Day celebrations. The municipal buildings were lighted by sixty-six 1000-watt floodlight projectors erected on the roofs of two adjacent structures and the main tower was illuminated by ten similar units. Four thousand electric lamps were hung in festoons from the Scott monument in the square to tramway poles at the four corners. Apparently this was in some contrast to illumination in London,[119] where, owing to trouble with strikers on the part of the electrical trade, and the shortage of coal, material and labor on the gas side, the building illumination did not come up to what it would have been had conditions been normal.

The extra illumination of a city's parks[120] by floodlighting has been carried out in an eastern city. As many as thirty-two 1000-watt lamps have been placed on high steel towers and produce an illumination covering a wide radius. A beautiful example of the possibility of artistic effects[121] by the use of light was seen at the N. E. L. A. Convention at Pasadena, in the floodlighting of the Japanese garden of one of the hotels. Six 500-watt projectors, each containing 400-watt lamps, were mounted at heights from 25 to 35 ft. (7.6 m. to 10.6 m.) and covered the main section of the garden and also illuminated the tall eucalyptus trees in the neighborhood. In addition, the main flower garden and the tropical gardens were lighted by combinations of utility lights, floodlights and reflectors. In all, 93 units were used with a power consumption of 30 k. w.

On the occasion of the last visit of the Prince of Wales to Niagara Falls, he participated in the ceremony inaugurating the floodlighting of the Horseshoe Falls.[122] A battery of nine banks of nine 1000 watt lamps, each located on a power house roof on the Canadian side and in suitable reflectors, throws light to dis-

[118] *Elec.*, Aug. 22, 1919, p. 204.
[119] *Gas Jour.*, July 22, 1919, p. 170.
[120] *Elect. Cont.-Dealer*, June, 1920, p. 126.
[121] *Jour. of Elec.*, July 15, 1920, p. 67.
[122] *Elec. News* (Can.), Nov. 1, 1919, p. 23.

tances ranging from 800 to 1400 ft. (244 m. to 427 m.) An additional set of nine lamps is located on the roof of Table Rock House. Considerable light is reflected from the spray, increasing the illumination of adjacent roadways. The Prince's Canadian visit was also made the occasion for special illumination[123] of the Windsor railway depot at Montreal where 7700 incandescent lamps were used for outline lighting and making up special designs, such as the "Prince of Wales Feathers."

Aerodromes.—The lighting of the landing space surrounding an aerodrome[124] is an extremely important factor of night flying. This subject has been given considerable attention in Germany, as may be seen from references in the 1916 Report, and it is still being studied. An ingenious arrangement for this purpose is formed of eight bucket lights sunk in the ground symmetrically around a central light and about 40 m. (131 ft.) from it marking the cardinal points of the compass. Four lights are always on, the remaining five, forming a pointer, being controlled by a weather vane so as to give the airmen the direction of the wind. The buckets are supplied with thick glass covers so that they can be run over without damage. Other developments are light-houses with wandering fan-shaped beams and aeroplane landing projectors.

INTERIOR ILLUMINATION.

In a bulletin of the U. S. Public Health Service,[125] entitled, "The Lighting of Industrial Establishments," attention is called to the fact that the importance of an adequate hygienic and well distributed system of artificial illumination is becoming pretty well recognized, but that the need for regular maintenance and cleaning is apt to be overlooked in some cases.

Schools.—In a new school in Quebec[126] the school lighting code of this Society was used as a guide in designing the lighting system, the code intensities being provided for as closely as possible. Daylight requirements were figured at double the foot-candle values given by the artificial light. Window area was figured at least 25 per cent. of floor area and the ratio of window height to room width was made not less than one to two. Semi-indirect

[123] *Elec. News* (Can.), Nov. 15, 1919, p. 29.

[124] *Elec. Rev.* (Lond.), Apr. 9, 1920, p. 465.

[125] *Ill. Eng.*, Sept., 1919, p. 273.

[126] *Elec. News* (Can.), Oct. 1, 1919, p. 52.

lighting was provided for in the class rooms by using dense glass bowls and 75-watt electric lamps and spaced so as to give a minimum illumination of four ft. c. on the desk tops. Stair cases, halls, corridors, lavatories, and play rooms were given direct lighting fixtures of a sanitary type to permit of easy cleaning. Direct lighting was also used in the dining room and kitchen, where the illumination on the tables was 3 ft. c. This value of illumination was provided in the assembly hall by semi-indirect pendant fixtures with some side wall brackets. In a high school in this country special fixtures were designed to enable the use of both gas and electricity for lighting purposes.[127] In the class rooms the semi-indirect system is employed, the inverted bowl containing three gas mantles and three electric bulbs. The bowls are so supported that a quarter turn disengages them for dusting and cleaning purposes. The auditorium is lighted by electric lamps overhead and side wall brackets, all of the semi-indirect type. In the kitchen, ornamental single mantle gas lamps are used. Foot-candle readings in the class rooms showed for daylight a variation from 2.5 to 8.5; for gas a variation from 4.6 to 6.0 and for electricity from 4.25 to 6.0. A unique use of anti-aircraft searchlights[128] has been made in a University in Paris. These lights furnish an intense illumination on subjects prepared for dissection so that by the use of a reflecting prism and lens a view of the actual operation of dissection may be projected on a screen and thus shown simultaneously to a large class of students, enabling each one to follow every detail.

Halls and Theatres.—The lighting of the famous Albert Hall in London has been modernized[129] by the installation of sixteen 1000-watt gas-filled tungsten lamps with vitreous enameled metal reflectors. It is stated that the improvement in illumination is not due to a greater amount of light than that furnished previously by the old arc lamps, but to a better distribution.

The moving-picture theatre is not the only class of public buildings which is utilizing totally indirect lighting.[130] A theatre devoted to vaudeville may be cited as an instance where the sub-

[127] *Am. Gas Eng. Jour.*, Mar. 20, 1920, p. 219.
[128] *Pop. Mech.*, Nov., 1919, p. 745.
[129] *Elec.*, June 18, 1920, p. 673.
[130] *Elec. Wld.*, Jan. 3, 1920, p. 4.

ject of illumination was given as much consideration in the planning of the building as the structural steel work, and the auditorium and stage are lighted entirely by indirect fixtures. The ceiling and walls are decorated in colors, but so combined that wherever one having a low cœfficient of reflection has been used, another with a high cœfficient has been worked in to balance the effect. The lobby has a graduated illumination ranging from 20 ft. c. to 5, this being the illumination of the auditorium with all lamps lighted. The entire auditorium, with the exception of a small section of the rear is lighted by an immense single fixture, 12 in. (30.5 cm.) in diameter, which is an inverted cone-shaped bowl of composition material applied to metal lath on a steel framework, the whole weighing approximately 3600 lbs. (1630 kg.) It carries eighteen 500-watt lamps and six 200-watt lamps, besides three 500-watt units to be mentioned later. A small inverted bowl at the apex of the cone contains eight 40-watt lamps which serve to illuminate the under surface of the fixture and also to provide sufficient illumination to find seats when pictures are being shown. The three 500-watt lamps send light through three glass paneled cartouches in the periphery of the fixture to illuminate the proscenium arch. Special attention has been paid to the lighting of the foyer, stairs, men's and women's rooms, and exit lights. For the last named purpose, a 10-watt ruby lamp has been used throwing light on a cartouche having the word "out" lettered in gold on a white background.

Always a fertile field for innovation, the theatre is the setting for many unique ideas in illumination. The large number of new theaters built for moving-picture purposes has furnished an opportunity[131] for novel installations which are constantly being reported. The desirability of a sufficient amount of general lighting to enable patrons to be seated or to leave at any time during the performance, coupled with the decided objection to any sources visible enough to distract attention from the screen has made the use of totally indirect fixtures popular in this class of lighting. In one new theater however, a semi-indirect effect is obtained by the use of frosted glass urns decorated in ivory and gold, and mounted on lambs' heads in gold and green in keeping with the style of architecture. The fixtures are located between

[131] *Mov. Pic. Wld.*, Dec. 27, 1919, p. 1135.

each of seven pairs of pilasters on the side walls. A general diffused illumination is also obtained by light from fifty-six 100-watt lamps shining through ten glass panels in the ceiling. The lamps are arranged on three circuits, permitting full, secondary or low illumination, and are graded to give the least light at the screen part of the house and the most light at the entrance. Recent British practice in lighting of cinema theatres is illustrated by a theater[132] where the entrance and crush halls and the foyer are lighted on the semi-direct principle. In the auditorium the direct system is also used and the main ceiling fixtures consist of special octagonal lanterns having latticed sides and built into the roof. The bottom is fitted with an obscuring bowl in which is placed the main lamp, while auxiliary red lamps are arranged to throw a glow through the latticed openings of the sides. Special attention has been given to the orchestra lighting.

Very bizarre lighting effects[133] are to be found in a big German theater. In the foyer, curving walls merge into a domed roof supported by mahogany columns, the upper portion of each one formed by many disks that radiate orange and blue light from concealed bulbs. The lights increase in intensity as they near the top of the column and the two colors alternate, no other colors being used.

Hotels.—An unusual problem in interior illumination was presented by the lighting of a large circular lounging room or atrium of a hotel.[134] The room is 200 ft. (61 m.) in diameter and 110 ft. (33.5 m.) high, with steel roof trusses converging to the centre. Indirect lighting is obtained from an enormous, steel-framed fixture 24 ft. (7.3 m.) in diameter placed directly under the hub of the roof. It contains eighteen 1000-watt electric lamps arranged in two circular tiers. Around the outside of the inner surface of the fixture are placed glass mirrors which reflect the light outward and upward. A general illumination of from 1 ft. c. up is obtained on the floor and walls. The brightness of the fixture and adjacent roof portions varies from 0.94 millilambert to 4.35 millilamberts.

Gymnasiums.—An examination[135] of fifty-two typical college, high school and Y. M. C. A. gymnasiums showed that nearly 50

[132] *Elec. Rev.* (Lond.), May 14, 1920, p. 612.
[133] *Pop. Mech.*, May, 1920, p. 672.
[134] *Elec. Wld.*, Apr. 24, 1920, p. 940.
[135] *Elec. Rev.* (U. S.), June 12, 1920, p. 974.

per cent. employed old style equipment consisting of lamp cluster bodies with flat white-glass or enameled-steel reflectors and protected by wire guards. Twenty-two having modern equipment showed a minimum wattage per sq. ft. of 0.42 and a maximum of 2.0 with an average of 0.78. The foot candle illumination was between 4 and 5 and the lamp size varied from the 60-watt vacuum tungsten lamp to the 750-watt gas-filled type. The lighting of eight swimming pools showed a variation of from 0.3 to 0.7 watt per sq. ft. An investigation of lighting conditions in thirty armories[136] showed that ten were provided with deep-bowl, dense-opal, direct lighting fixtures; six were equipped with enclosed globes of opalescent glass with external porcelain enameled-steel reflectors; five had deep-bowl, mirrored-glass reflectors; four had deep-bowl, prismatic-glass direct lighting reflectors; one had enclosing globe units without external reflectors. Actual power consumption for armories with modern floors was found to vary from 0.25 to 0.55 watt per sq. ft., the average being 0.37. The illumination varied from two to five ft. c. Where tanbark floors were used the watts per sq. ft. and foot candles were about the same. In general, in armories it was found that while the lamps used ranged in size from 300 to 1,000 watts, the 750 and 1,000-watt units predominated.

Stores.—Knowledge of present practice in show-window lighting was obtained from a study of installations in 125 high class dry goods and department stores scattered through 40 cities of this country.[137] Fifty-three were found to be using one piece mirrored-glass reflectors; forty-three use mirrored-trough reflectors with lamps placed horizontally; sixteen use prismatic-glass angle reflectors and five use dense opal bowl-shaped glass reflectors. From the size of the lamp and the outlet spacing, it was found that a grand average of the power consumption was 53 watts per running foot (0.3 m.) of window.

An echo of the effect of the coal shortage was seen[138] in show window illumination which was produced in many cases by kerosene lamps and candles, but in one instance by a battery of flashlights which thereby served a double purpose. By using three

[136] *Elec. Rev.* (U. S.), June 12, 1920, p. 969.
[137] *Elec. Rev.* (U. S.), Apr. 10, 1920, p. 595.
[138] *Elec. Merch.*, Jan., 1920, p. 14.

lighting circuits,[139] the lamps of each circuit furnishing light of one of the three primary colors, a clothing establishment has made it possible for a salesman to demonstrate goods under a wide variety of color values. Brightening and dimming of the lights is accomplished by dimmers of the type used in theatres, and six-push-button switches give control of any desired color or intensity.

Transportation.—An exhaustive statement[140] of present practice in lighting of railway coaches and pullman cars is to be found in the 1919 report of Sub-Committee "A" on Car Illumination, of the Committee on Illumination of the Association of Railway Electrical Engineers. It is pointed out that fixtures for car lighting purposes have been changing from the old ornate and inefficient type to a class, which, while still artistic, combine that feature with good lighting results. Data are given on the average illumination on a 45° reading plane, both for electric and gas lighting systems, as well as the results of tests on the effect of blackening of shades and bulbs. Subway stations and connecting passages[141] offer a problem in illuminating engineering in which two factors, glare and safety, must be given special attention. The importance of planning such an installation in advance is well illustrated in a case where glare was taken care of by fixtures in the form of boxes inserted in the wall and covered with translucent glass plaques flush with the wall surface. The white tile coating of the latter would make the avoidance of glare almost impossible with any other type of fixture. Inside each box are two lamps connected on independent circuits so that the failure of one does not put the lighting system out of service, and further it permits of a reduction of illuminaton at periods when that is desirable. A passenger station at one end of the tunnel was too far advanced when the lighting plans were made to permit of the use of flush fixtures and hence pendant units with opal-glass diffusing sides and bottoms were employed.

Factories.—In the report of the English Electrical Inspector of Factories,[142] reference is made to a development in localized lighting in workshops, where induction motors are used to drive individual machines, advantage being taken of the fact that the stator

[139] *Elec. Rev.* (U. S.), Jan. 24, 1920, p. 165.

[140] *Ry. Elec. Eng.*, Oct., 1919, p. [illegible].

[141] *Elec. World*, Sept. 6, 1919, p. [illegible].

of an induction motor is a transformer. A small fine wire coil is placed at the bottom of the slot of each machine, furnishing a 21-volt potential. Headlight lamps of this voltage are employed with especially designed reflectors attached to fittings having a universal joint so that the lamp can be turned in any direction. As high as 15 ft. c. are said to be obtained at a distance of 15 in. (38.1 cm.), while the expenditure of energy is very low as compared to that usually required where 110 or 220 volt circuits are employed. Another advantage claimed is, that since the lamps are on the power circuit, in cases where this is independent of the main overhead lighting system, trouble on either does not leave the shop in darkness. Another example of the British practice in factory[142] lighting is to be found in the case of an aeroplane plant. The large main bays are lighted with 1000-watt lamps in semi-indirect pendant type fittings suspended at a height of 30 ft. (9.1 m.) and 40 ft. (12.2 m.) apart. 300-watt lamps are used in the galleries. The average illumination throughout the factory is 3.5 ft. c. In still another case, twenty-two 500-watt[143] lamps are used in focusing metal reflectors 28 ft. (8.5 m.) from the floor. The machine shop has twenty units suspended 38 ft. (11.6 m.) from the floor while the foundry uses sixteen 300-watt units 25.5 ft. (7.8 m.) from the floor.

Many railway shops were originally lighted by enclosed arc lamps,[144] which were replaced by high-wattage vacuum tungsten lamps and later by gas-filled tungsten lamps. The absence of proper reflectors for the last named lamps has caused, in some cases, unsatisfactory illumination, particularly, in small railway shops which have been considered hard to light because of the many obstructions generally present. An instance where this was remedied without increasing the current consumption is to be found in a shop where 300-watt lamps mounted in deep-bowl reflectors at a distance of 19.5 ft. (5.9 m.) from the floor, replaced 500-watt vacuum lamps mounted in shallow reflectors. The number of lamps needed was determined on a basis of 0.3 watt per sq. ft. of floor space.

Mines.—In a discussion before the London Illuminating Engineering Society,[145] on the effect of the peculiar conditions of illu-

[142] *Elec. Rev.* (Lond.), Aug. 29, 1919, p. 267.
[143] *Elec.*, Feb. 27, 1920, p. 228.
[144] *Ry. Elec. Eng.*, Dec., 1920, p. 439.
[145] *Elec.*, Mar. 5, 1920, p. 238.

mination in mines on eyesight of miners, it was suggested that in coal mines, 0.1 ft. c. be adopted as a tentative standard, and that a complete study, both of eyesight and illumination be made in the English mines by a committee on which both ophthalmic surgeons and photometric experts were represented.

FIXTURES.

As indicated by the display[146] at the fixture manufacturers meeting last February, the candelabra fixture has been the dominating idea of the year in the development of residence lighting units. In many cases this means exposed sources with the consequent disagreeable glare, but this difficulty will probably not be entirely done away with until the educational work of this Society has been carried further. The idea of making a fixture whose appearance can be easily and inexpensively changed by the householder has been steadily growing, and it is noteworthy that an effort has been made to so fix the conditions that the changes in appearance will not interfere with the production of good illumination. The importance of keeping shades and reflectors as free as possible from dirt and dust is realized in designs in which this feature is particularly looked out for.[147] Some years ago reference was made to the ingenious designing of globes and reflectors for use with gas lighting so that they resembled those made for electricity. A reversal of this idea occurs[148] in an electric fixture which has been worked out for use in locations where both systems are employed and which is a duplicate in external appearance of a gas unit made by the same company.

Reflectors.—The production of fixture designs of the two-part type, upper canopy reflector and totally or partially enclosing lower reflector, still continues,[149] a fact which indicates the popularity of this class of fixtures, and of semi-indirect lighting in general. A new unit for general indoor lighting[150] has an arrangement of lamp, reflector and bowl, which is somewhat out of the ordinary. The bowl is an urn of translucent glass with surface ornamentation in the classic and gothic periods and is supported by a metal canopy. The lamp is fixed so that the fila-

146 *Elec. Rec.*, Mar, 1920, p. 121.
147 *Elec. Merch.*, Apr., 1920, p. 216.
148 *Elec. Rec.*, Dec., 1919, p. 338.
149 *Elec. Rev.* (U. S.), Aug. 23, 1919, p. 331.
150 *Elec. Rev.* (U. S.), Jan. 10, 1919, p. 85.

ment comes in the horizontal plane of the top of the urn, instead of near the centre as is usually the case, and is surrounded by a steel porcelain-enameled shallow reflector. Ventilation is arranged for in such a way as to minimize the effect of dust or dirt entering the fixture.

A lantern which conforms to the gothic style of architecture[151] and is suitable for use in churches or halls is arranged to be equipped for either direct or indirect lighting. In either case extra light is provided for the glass panels. A modification of the "shower" type of fixture[152] has the central lamp and shade attached to a cord, which, when not in use, is wound on a spring-operated drum inside the ornamental plate to which the remaining lights of the "shower" are attached. When desired this lamp may be drawn down so as to furnish localized light for reading, etc.

A reflector of the type ordinarily used commercially has been devised for attachment[153] to any ordinary socket in a home. It is of porcelain-enameled spun-steel and fits on the socket, which carries a shallow diffusing shade with an opening large enough to admit the lamp which should be bowl-frosted. A side-wall fixture which has two lights,[154] one for all-night use, is made of white glass having a marble-like appearance. The auxiliary night light, similar to, if not the same as the one described in last year's report, is a 2 c. p., 6-volt, automobile lamp in a bayonet socket, equipped with a separate switch and wired to a transformer concealed in the base.

While there is little that seems to be strikingly different in the design of table and other portable lamps, a number have been brought out in the past year.[155] Among these may be mentioned[156] a students electric lamp of simple design made to replace the oil and gas lamps formerly so generally used at institutions of learning. It has a mahogany base and short standard from which projects a wire rod extending up a short distance and continuing at right angles after a circular turn which serves to take

151 *Elec. Rev.*, Mar., 1920, p. 142.
152 *Pop. Mech.*, Apr., 1920, p. 516.
153 *Elec. News* (Can.), Dec. 15, 1919, p. 45.
154 *Elec. Rec.*, June, 1920, p. 371.
155 *Elec. Rec.*, Oct., 1919, p. 234, 235.
156 *Elec. Rec.*, July, 1920, p. 12.

up jars. At the end of the rod is an ordinary socket and lamp, the latter supporting a small metal shade. The use of lights in and around aquariums in general adds to their attractiveness. A Japanese inventor utilizes[157] a gold-fish bowl of tall cylindrical or similar shape as the base of the lamp itself, exactly as porcelain vases have for some time been used for this purpose. A glass tube through the centre of the bowl carries the electric wires. The Statue of Liberty has been used in several designs for unique lamp standards,[158] in one case as a table lamp and in another[159] as part of an ink-well stand.

The use of decorated parchment shades[160] for portable lamps seems to be growing. Silk shades for wall bracket lamps[161] and small portables, such as those used on dining tables, dressers, etc., have been available for a long time, generally fitted over small wire frames. Cloth shades have been devised of a similar style, but made of linen with a choice of a number of colors and arranged to slip over the end of the bulb. Unless properly treated and except where proper precautions are taken, these shades should not be used in cases where they are liable to be scorched by the lamp.

Industrial Units.—A reflector, designed[162] especially for use in factories, is so shaped that it will illuminate a circle whose diameter is equal to the height of the lamp, or twice the height of the lamp from the floor. It is made of unbreakable, heat-resisting material, having a silvered surface protected by a coat of varnish. It is claimed that 72 per cent. of the light is usefully employed. In the evolution of the modern reflector used in industrial plants and workshops, it was early recognized that where white or light-colored ceilings were present, the use of opaque shades in which all the light is reflected downward produces undesirable sharp contrasts in brightness; on the other hand, objections to the use of glass in such locations has lead to the development[163] of the enameled, all-metal reflectors. In order to get

[157] *Pop. Mech.*, Feb., 1920, p. 183.
[158] *Elec. Rec.*, Sept., 1919, p. 142.
[159] *Elec. Rec.*, June, 1920, p. 371.
[160] *Elec. News* (Can.), July 1, 1920, p. 50.
[161] *Elec. Rec.*, Oct., 1919, p. [illegible]
[162] *Elektro. Rundschau*, July [illegible], 1919.
Abs. Elec. Wld., Feb. 7, 1920, p. 334.
[163] *Elec. Rec.* (U. S.), Nov. [illegible], 1919, p. [illegible]

some light to the ceiling the ordinary types have been modified by the addition of a vertical glass diffusing part extending above the centre, forming a sort of cap. This glass top is in little danger of being broken and gives enough upward radiation to relieve sharp contrasts without seriously impairing the efficiency of the unit. Another modification of the enameled steel reflector industrial unit[164] has the lamp inside a glass globe 5 in. (12.7 cm.) in diameter, the lower part of which is frosted. A deflector plate is fitted around the neck of the lamp to prevent loss of light at that point.

For absolute security in munition works, shell-filling factories, air-ship factories and sheds,[165] it was considered necessary during the war to have lighting fixtures absolutely gas-tight. This inspired the development of units using as high as 300-watt, gas-filled tungsten lamps in clear glass globes hermetically sealed with rubber gaskets to metal casings provided with ventilating fins. It was claimed that without other ventilating devices such as are ordinarily required for such high-powered lamps, the temperature of the metal parts never rose above 140° F. with the lamp in continuous operation. In cases[166] where the use of such clear glass vapor-proof fittings would cause discomfort due to glare, it has been necessary to add diffusing shades around the globes. A single-piece combined globe and diffusing element has been brought out to obviate this difficulty. It has a prismatic construction with downward directing prisms in the upper portion and with refracting and diffusing prisms in the lawer part. They are made in sizes suitable for lamps ranging from 40 to 150 watts in connection with standard vapor-proof fittings.

Special attention has been paid to development of reflectors for drop-cord lamps.[167] An example of this type for industrial use which may also be used for ceiling attachments or chain suspensions is of the two-part class. It is all metal and intended to combine the vertical and horizontal features of both the deep and shallow bowl units without cross reflection, deep shadows or glare. A simple adjustable unit[168] which may be attached to a lamp socket is made up of two hollow brass spheres, pivoted on

164 *Elce. Merch.*, May, 1920, p. 265.
165 *Elec.*, Aug. 22, 1919, p. 196.
166 *Elec. Rev.* (U. S.), Sept. 13, 1919, p. 456.
167 *Elec. Wld.*, Jan. 10, 1920, p. 105.
168 *Pop. Mech.*, Jan., 1920, p. 21.

a bracket that fastens to the socket. Thumb screws permit the spherical segments to be set either together above the lamp, throwing the light down, or below the lamp throwing the light up on one side or in an intermediate position. In order to utilize[169] a single lamp to the best advantage and still screen the light from the eyes of the operator, a movable shade has been designed especially for sewing machines or others of a similar character used in work shops. It has four projecting leaves and may be attached to any ordinary drop-lamp socket.

Street Lights.—In street lighting the tendency,[170] except in units mounted 25 to 30 ft. (7.6 to 9.1 m.) above the street, is toward the use of standards surmounted by single globes rather than the clusters which were quite popular a few years ago. Data on the relative light distributions of the two types have been prepared. For some years the value of "White Way" lighting as an advertising magnet has been recognized,[171] but in California advantage is being taken of the lighting standards as a means of identifying and pleasurably recalling a location. Los Angeles, Riverside, San Bernardino, Seal Beach, Alhambra, and San Gabriel have already adopted lamp posts whose design is symbolic, either of some great historic tradition or some local attraction. At Riverside, the mission feature of the community is exemplified in a concrete post, made like a chapel bell-tower with three mission bells hung in a triangle, and a cross at the top of the design. The "Arrowhead" street lamp post is used in San Bernardino, while at Seal Beach, a post with three upright seals at the top forms the standard type. The mission idea in different form is carried out in the posts of San Gabriel and also in Alhambra. In Los Angeles the Shriners have had installed in front of their auditorium, posts topped by the Shriners' emblem marked out in electric-sign fashion. The idea has so many possibilities, particularly in these days of auto touring that the chambers of commerce in other California cities are advocating it as a means of publicity for their respective localities.

What is said to be a new idea in a sign to give street names has a heavy cast iron square frame[172] with a raised centre fitted with

[169] *Elec. Rev.*, Sept., 1919, p. 443.
[170] *G. E. Rev.*, Dec., 1919, p. 1044.
[171] *Sci. Amer.*, Apr. 17, 1920, p. [illegible]
[172] *Sci. Amer.*, Sept. 27, 1919, p. 317.

heavy plate glass. The latter is colored red with the name in white letters. The whole is bolted to a concrete base, and is provided inside with an incandescent lamp for night illumination. It is claimed that the names of the streets can be read from an automobile at a distance of 100 ft. (30.5 m.).

The "remote control" principle[173] is not needed in street lighting systems using electricity to the extent to which it is advantageous where gas is the illuminant. Nevertheless, there are places where it is desirable to be able to put on or to shut off certain lamps independently. Various devices have been evolved for this purpose, and one brought out in England has recently been described. The control is through selection by resonance, a switch at any point being operated by resonance currents produced in it by an a. c. of low voltage and high frequency superimposed on the regular supply voltage at the station. The switches are timed to respond to a particular frequency only. The "ripple" voltage is between 2.5 and 5 per cent. of the supply voltage and does not disturb the rest of the system. The switches are said to be immune from momentary disturbances caused by short circuits, surges and other causes affecting the regular supply. In this country,[174] also, attention is being given to remote control, and in particular to time switches and relay systems. One of the latter in process of installation is designed to light all lamps of a five-light cluster at dusk, turn out four at midnight, and the remaining lamp at dawn.

Accessories.—In order to still further favor the householder in his desire for variety, an epoch-making development in lighting fixture suspensions has appeared, so that it is now possible to attach a fixture just as any other appliance is attached, by means of a plug. Several methods of accomplishing this result[175] have been worked out. In one the suspension member slides over a horizontal trackway while two prongs are thereby pushed into clips in a hinged section. The latter, when not in use, folds up becoming flush with the plate. A similar arrangement is made for a side-wall bracket. Another device has two curved hooks pointing in opposite directions, which are inserted in the ceiling slots, and placing the fixture chains in position spreads the hooks.

173 *Elec. Times*, Feb. 19, 1920, p. 150.

174 Report of Lighting Sales Bureau, May, 1920.

175 *Elec. Merch.*, May, 1920, p. 246.

The slots for contact are of the standard type and take any regular push attachment plug. In still another arrangement, the outlet box, by means of a threaded construction, is used to support ceiling lamps, stem fixtures, or chain hangers, providing both electrical and mechanical connections.

An adjustable hanger[176] for lighting-fixture bowls fits any size from 12 to 18 in. (30.5 to 45.7 cm.) in diameter. The bowl need not be pierced or otherwise provided with holes and a stem, single or triple-chain suspension may be employed. Interchangeable trimmings at the ends of the hanger permit the addition of shower shades or the support of candles. Provision for lights in the bowl is also included.

The use of vases[177] as bases for table lamps has become so common that a special fitting has been worked out which provides the wired standard, canopy, sockets, and cord and obviates the necessity of boring a hole in the vase to admit the wiring. Three adjustable rubber clamps on the base grip securely either the outside or the inside edge of the vase. The standard, at the top of which are two pull-chain sockets, can be raised or lowered to suit the size of the vase and shade. The popularity of electric appliances[178] for the household has directed special attention to the design of double-outlet plugs. An illustration of this type of plug has a one-piece "bakelite" insulating body and can be used with the same shade holder as the ordinary brass socket. The auxiliary outlet is set at a convenient angle for use with an extension cord connecting another light or appliance. An adaptation[179] of the tumbler switch idea so commonly used in England has been made in the case of a new lamp socket. The ordinary "key" has been replaced by a lever which in the up position indicates that the current is off, and is merely pushed down to turn the current on. There are frequently occasions[180] when it would be convenient, if, after turning off the switch of an incandescent lamp, the lamp should remain lighted for a more or less brief period of time. This want has been considered in a new socket which is fitted with a thermostatic device consisting of two metal strips with dif-

[176] *Elec. Rev.*, Dec., 1919, p. 339.
[177] *Elec. Wld.*, Nov. 1, 1919, p. 916.
[178] *Elec. Rec.*, Sept., 1919, p. 142.
Elec. News (Can.), May, 1920, p. 50.
[179] *Elec. News* (Can.), Nov., 1919, p. 23.
[180] *Elec. Rec.*, June, 1920, p. 370.

ferent expansion coefficients, and wound with a piece of german silver wire. When the circuit is closed, the wire heats up and in turn the metals which make contact, and when the switch is turned off, the action is reversed. The length of time the lamp remains lighted is controlled by a set screw which regulates the gap between the metal strips and the time interval may be varied from 15 seconds up to one-half hour.

A device originally conceived for the purpose[181] of making it easier to remove lamp shades for cleaning or replacement purposes has been modified so that it forms a lock to prevent loss by theft. Another locking device[182] has a small metal pin with a triangular head which screws through the porcelain base, being threaded into a hollow screw which fastens the socket into the porcelain. The lamp cannot be removed without a special tool.

Developments have been made in Germany[183] in the holders by which shades and reflectors are attached to lamp sockets. While no sizes have been standardized, two diameters have become common, that is 57 mm. and 78 mm. (2.2 and 3.1 in.). In one type tightening screws have been done away with by replacing them by elastic grip jaws, a lever being provided to lock the jaws in position. Shade holders have been worked out[184] to overcome the effect of vibration in industrial locations where this difficulty is prevalent, the result being accomplished by preventing the loosening of the reflectors in the holder.

A system of wiring and conduit combined with a flexible arm carrying the lamp and reflector forms an addition to the list of fittings for providing localized[185] lighting and to replace drop cords. The arm consists of a length of rigid conduit terminating in a ball and socket joint at one end and in a length of flexible metallic conduit carrying the reflector at the other end. The arm, usually 7 ft. (2.1 m.) long, permits placing the lamp anywhere within a radius of 8 ft. (2.4 m.).

In Germany[186] a method has been worked out for making "concave mirrors of any curvature mathematically accurate from an almost unbreakable material in a very cheap manner." Pure

[181] *Elec. Rev.* (Lond.), Oct. 17, 1919, p. 493.
[182] *Sci. Amer.*, June 12, 1920, p. 641.
[183] *Helios*, May 16, 1920, p. 1695.
[184] *Elec. Rec.*, Mar., 1920, p. 143.
[185] *Elec. Merch.*, Feb., 1920, p. 101.
[186] *Helios*, Mar. 28, 1920, p. 1055.

silver is deposited for a mirror surface and protected by a colorless lacquer. An advisory committee of the International Electrotechnical Commission has been appointed[187] to deal with the question of international interchangeability of screw lamp caps and lamp holders.

As stated in the introduction, attention has again been called[188] to the importance of cleaning lamps and reflectors in order to maintain efficiency in lighting systems. Data have been worked out showing the approximate loss, in percentage of initial illumination on the working plane for typical light installations, after various periods of time without cleaning and also the cost for cleaning in certain cases. The effect of dirty walls and ceiling has also been noted.[189] In an office installation where the indirect system was used, the foot-candle illumination on the working plane was increased from 2.7 to 7 by cleaning the reflectors, renewing the lamps and re-finishing the walls and ceilings in their original tone.

PHOTOMETRY.

Very little has been reported on the subject of photometry during the past year, and what has appeared has been more in the nature of apparatus and methods for special purposes than for the ordinary measurement of luminous sources.

Instruments.—A study of the effect of discoloration[190] in the paint used on the inner surface of an Ulbricht sphere indicated that where the color differences are not more than those encountered in the measurement of gas-filled tungsten lamps in terms of vacuum tungsten lamps, the paint can depart appreciably from whiteness without causing a very large error. Within the last few years[191] a number of different methods and instruments have been devised to measure the reflection factors of diffusing surfaces, and a new instrument for this purpose utilizes a small Ulbricht sphere with a segment cut away leaving an opening to be closed by the surface under test. In the instrument described, the portion cut off formed about 10 per cent. of the total sphere area. The test surface is illuminated by a source at the end of

[187] *Elec. Times*, Oct. 30, 1919, p. 338.
[188] *Elec. Rev.* (U. S.), Feb. 14, 1920, p. 265.
[189] *Elec. Wld.*, Jan. 24, 1920, p. 204.
[190] *Jour. Frank. Inst.*, June, 1920, p. 787
[191] *Jour. of Opt. Soc. of Amer.*, Jan., 1920, p. 9.

a tube opening into the sphere at a point diametrically opposite to the surface under test, and this tube may be moved to another opening in the sphere where it will illuminate a part of the sphere surface. Measurements are made of the illumination of a small window by a portable photometer in the usual manner. Experimental results on a series of diffusing surfaces with different reflection factors showed very good agreement with results obtained by integrating point-to-point measurements. The tests included magnesium carbonate which was found to have a reflection factor of 99 per cent., and, as this value seemed very high it was verified by using two other methods. A modification of the method just described is applicable in cases where the material to be studied can be made the inner surface of a small sphere,[192] the test equipment consisting of a sphere that has one or more removable sections. A beam of light is projected by means of lenses through an opening in the sphere, and the illumination of the window is measured in the usual way. Measurements are made first with one section of the sphere removed and then replaced and another section removed. Combining the results gives an expression in which the reflection factor comes out as a numeric. It was found that the best conditions for practical use are obtained when the first section is as large as possible and the second section one-half to three-fourths as large. The reflection factor of magnesium carbonate as found by this method is given as 97 per cent.

The use of the photometer to determine when two incandescent lamps have the same color has become quite common practice in the last few years. In connection with some work on physiological optics, the sensitiveness of this method was tested[193] for different photometers, different intensities of illumination and different hues. The method consisted in finding the least voltage change which would produce a noticeable difference in color tone. The results for white light showed that, of three photometers compared, the contrast form of the Lummer-Brodhun photometer was the most sensitive, the disappearance type next and the Bunsen photometer third. The same thing was true for the other conditions.

[192] *G. E. Rev.*, Jan., 1920, p. 72.
[193] *Am. Jour. of Psych.*, Jan., 1920, p. 77.

While a great deal of effort has been expended in the past to eliminate shadows, very little has been done directly in reference to measuring their density. A device for this purpose[194] consists of fifteen sectors tinted in a series from white to dead black, the coefficient of reflection of each sector with respect to white being indicated by a number. With a white space between two adjacent tinted ones, the sectors are arranged in a circle on a disk with a rod at the centre. The disk is turned until with one of the light sources under consideration turned out, a shadow of the rod is cast in the white space intermediate between two tinted areas such that there is approximate balance of brightness. This shadow is illuminated by the other light sources and calling the original illumination due to all E_0, and that due to the light withdrawn E_1, then the ratios $(E_0 - E_1) : E_0$ and $(E_1) : E_0$ are readily determined.

Methods.—A very novel method of computing the distribution of illumination on the working plane has been devised in Germany.[195] A concentrated filament, approximately a point source is mounted in a spherical bulb which has etched on its surface meridians and parallels dividing it into one hundred parts of equal area (deka-space-degrees). The lamp is mounted above a drawing of the space to be illuminated and the etched lines cast shadows making it possible to count the number of space-degrees on the plane. From the photometric distribution curve the flux in each zone is determined and the space-degrees in any zone on the plane have the same flux as that from the corresponding zone on the lamp bulb surface. The total flux incident on the surface will be the sum of that contributed by each lamp. A modification of this idea subsequently suggested, involves a cubical box having a blackened inner surface and a removable bottom. For the latter is used any one of a series of glass plates on which are photographed the projection of the lines etched on the original bulb with suitable notations which would differ with the lamp used. The notation gives the flux per space-degree in each zone; the flux in the entire zone; the area covered by each space-degree for the height of the lamp; and the illumination in lux under each condition.

[194] *Ill. Eng.*, Dec., 1919, p. 341.
[195] *Zeit. f. Beleuch.*, Jan. 31, 1920, p. 13.

In order to predetermine the range of light-house illumination a laboratory experiment has been devised[196] in which a sieve is made up of a series of vertical metallic plates pierced with holes in groups of four of small diameter, rigorously calibrated and placed on parallel horizontal lines. The sieve is placed before the mirror reflector and the parallel beams of light passing through the holes are received on a screen and those which would reach the horizon are readily picked out. By turning the mirror, the region active in this direction may be determined. From a plot of the distribution, the range may be calculated.

In the photometry of lamps with reflectors where the inverse square law does not apply, certain conventions have become more or less standardized by practice. In the case of searchlights using parabolic reflectors it has sometimes been assumed that the inverse square law holds if measurements are made from a point in space behind the mirror. Experiments have been made[197] which indicate that for distances greater than a certain limiting value, the inverse square law can be applied if the distance is measured from the mirror itself. Allowances and corrections must be made for atmospheric absorption and for aberration.

A method has been described [198] for the graphical determination of the illumination produced from the polar candlepower curve of the source. It is based upon conditions of proportionality in similar triangles. Right-angled triangles and a compass are the only tools needed and the simplicity of the method is cited in favor of its practicability. It may also be used to construct the polar curve which will give a desired illumination curve.

PHYSICS.

It should be noted that measurements made during the eclipse of the sun in May 1919[199] furnished data which have been interpreted as confirming the relativity theory of Einstein and thereby causing a worldwide discussion of the subject. In connection with the study of absorption bands of certain chemicals, further work has been done[200] on the aluminum-spark method of producing strong ultra-violet radiation. A transformer was used,

[196] *Comptes Rendus*, Oct. 6, 1919, p. 616.

[197] *Zeit. f. Beleuch.*, Apr., 1919, p. 35.

[198] *Elek. Zeit.*, Jan. 8, 1920, p. 25.

[199] *Sci. Amer.*, Nov. 29, 1919, p. 537.

[200] *Rev. Gen. d'Elec.*, July 26, 1919, p. 25D.

having 160 volts on the primary side and 80,000 on the secondary. The current on the primary side could be varied from one to two amperes. The aluminum electrodes were placed in distilled water and connected in series with an auxiliary spark in air. They were connected in parallel with a battery of eight condensers of an individual capacity of 0.0045 microfarads and which combined gave 50,000 volts. Using a concave grating the spectrum obtained extended from 0.8 to 0.203μ. It was found necessary to keep the water in circulation. A considerable extension of the spectrum into the region of shorter wave-lengths[201] has been made with the use of a grating, constructed to obtain the maximum possible brilliancy, a new diffusion pump and the hot-spark-in-vacuo method. By this work three-fourths of an octave has been added to the ultra-violet spectrum, including ten zinc lines, below 0.05μ.

Revision of data[202] on the spectral energy curve of the acetylene flame confirms the conclusion that the energy distribution of this flame can be satisfactorily represented by that of a black body at 2360° K.

Properties.—Reflection factors have been obtained for a number of pigments,[203] emerald green, ultra-marine, crystal violet, methyl blue, crystal green, and vermillion. Values at wave-lengths varying from 0.692μ to 0.427μ were obtained in terms of those for zinc white, the pigments being coated on stout white cartridge paper.

A new instrument has been devised for the colorimetry[204] of nearly white surfaces using the principle that multiple reflections from similar surfaces accentuate selective reflection. Experiments with the instrument showed that among others, magnesium oxide and magnesium carbonate depart noticeably from whiteness, the latter being definitely yellowish. The need for an accepted definite standard of "white" was emphasized. A very unusual problem in color determination[205] was presented when the Colored Lights Section of the American University Experiment Station requested the development of a method for color-grading red flares. The flares submitted were classed as follows:

[201] *Sci.*, Aug. 8, 1919, p. 138.
[202] *Jour. Frank. Inst.*, Sept., 1919, p. 399.
[203] *Ill. Eng.*, Feb., 1920, p. 39.
[204] *Jour. Frank. Inst.*, Mar., 1920, p. 371.
[205] *Phys. Rev.*, Sept., 1919, p. 264.

(1) carbonate flares, burning with a yellowish red flame; (2) nitrate flares, burning with a comparatively purer red flame; (3) a standard railway red fusee. The problem was analagous to that of determining the illuminating values of flares used in the war, and referred to in last year's Report. It was found possible to make the measurement in spite of the erratic burning and great changes in intensity by using an Aron's chromoscope and having the light from the flare illuminate a magnesium block whose color could be compared with that of another block lighted by a tungsten lamp. By this method it was found possible to determine the energy distribution which matched in total color that of the flare.

There are two main types of phototelephony,[206] (the transmission of sound by means of light flux), one in which the emission of light from the source is modulated, the other in which the beam of light is changed after emission. An arrangement of Graham Bell's grid method utilizes a small concave mirror with a grid mounted in front of it. The mirror is attached to the diaphragm of a gramophone receiver, and the vibrations of the mirror cause fluctuations in the shadows cast by the grid on a second system at the receiving point. Successful trials have been made over a distance of half a mile (0.8 km.), the articulation being more perfect than with carbon microphones.

Luminescence.—An attempt[207] to explain luminescence, phosphorescence and fluorescence is found in a theory that in photoluminescence, the exciting light produces photoelectric separation of electrons from the atom in accordance with stated laws. Fluorescence is produced when there is an almost immediate return of the atoms to the parent atom; phosphorescence, when there is a slower return. By measurements[208] of the minimum energy required to ionize an iodine molecule in the normal state as compared with that required to ionize a fluorescing molecule evidence was obtained tending to confirm the theory that "the primary effect of the exciting light is to cause one or more electrons of a molecule to take positions or conditions of abnormally large potential energy, without being necessarily removed from the parent molecule. This additional energy is absorbed from the exciting light, and re-emitted as . . . . fluorescent radiation . . . . of

[206] *Elec. Rev.* (Lond.), July 18, 1919, p. 81.
[207] *Jour. Roentgen Soc.*, 1919, p. 33.
[208] *Sci.*, June 4, 1920, p. 571.

the same, of lower or of shorter wave-length than the exciting light, according as the return is accomplished in a single step, in several steps, or in a single step following the absorption of additional radiant energy."

Additional study has been made of the phenomenon of electrolytic luminescence[209] as shown by aluminum, magnesium, zinc, and bismuth when used as anodes. This phenomenon occurs only in an electric field and has an extreme intensity reaching, and even exceeding in the case of aluminum, the effect which would be produced in vacuum tubes running on 3,000 volts per centimeter and producing phosphorescence in the same metals by the action of cathode or canal rays. It is connected with a high polarization of the anode and the creation at its surface of an intense electric field. In a continuation of some previous work on fluorescence,[210] a French experimenter has confirmed the conclusion regarding the "optimum of fluorescence" reached by another experimenter and referred to in last year's Report. Thus he found that the phenomena of phosphorescence and of fluorescence are characterized by the property that the production from the process of excitation is at a maximum when the solution is very dilute and the exciting radiation is very feebly absorbed. It has been found possible to replace barium platino-cyanide for fluorescent screens[211] by the tungstates of magnesia. Such screens are said to be insensitive to physical and atmospheric agents, give a white luminescence and the radioscoped body shows up black.

Selenium Cells.—Experiments on the ultimate increase in conductivity of selenium cells when exposed to light, showed[212] for the cells tested that the increase is proportional to the fourth root of the light intensity instead of the square root as has been ordinarily accepted. The law was found to hold over a wide range of intensities. The method used was to determine the ultimate change in conductivity attributable to illumination by measuring the total increase in current resulting from exposure to light. Reference was made in the 1917 Report to a search for materials other than selenium which change their resistance when exposed

[209] *Comptes Rendus*, July 28, 1919, p. [illegible]
[210] *Comptes Rendus*, Sept. 22, 1919, p. [illegible]
[211] *Elec. Rev.* (Lond.), Oct. 31, 1919, p. [illegible]
[212] *Phil. Mag.*, May, 1920, p. [illegible]

to light and might therefore be used for light measuring purposes. As a result of this work it has been found[213] that a compound of thallium, oxygen and sulphur may be used to make a very sensitive cell. After careful preparation the material is first fused on a three-quarter inch quartz disk and then placed in an evacuated tube of flashed copper ruby glass. The point of maximum sensibility was found to be at 1.0μ and the average sensitivity such that the dark resistance was lowered by fifty per cent. when the cell was illuminated by a tungsten lamp to 0.25 ft. c. The resistance in the dark of different cells ranged from 5 to 500 megohms. The dark resistance varies inversely as the temperature.

PHYSIOLOGY.

The work of submarines and aeroplanes during the war emphasized the necessity of more information on the subject of visibility and a considerable amount of investigation along this line was carried out. Various phases of this subject have been treated in previous Reports and additional information will be found in this section.

Theory.—Two theories of vision have been suggested:[214] one, "that light absorbed in the black pigment may stimulate certain atoms into radioactivity and so cause the sensation of light;" the other, of color vision, "that the emission of electrons, probably by the pigment layer under light stimulus, is responsible for light sensation, and that where these electrons act upon the cones they excite color vision." In the latter case, efforts to detect a photoelectric effect by experiments of the usual kind on a bullock's eye failed.

Instruments.—The shortage of optical glass in this country during the war emphasized the importance of conserving this material as much as possible. This, among other reasons led to an investigation[215] of the relative merits of binoculars and monoculars as used in warfare. It included an experimental study of whether, under the appropriate conditions, both eyes together can distinguish small details with greater speed and accuracy than one eye alone, both under daylight illumination and under twilight illumination and also practical field tests. The results indicated

213 *Phys. Rev.*, Apr., 1920, p. 289.

214 *Nature*, Sept. 25, 1919, p. 74; Oct. 2, p. 92; Oct. 30, p. 175.

215 *Jour. Frank. Inst.*, Feb., 1920, p. 185.

"with equal mechanical convenience of using the glass, that the binocular use of the glass at best yielded no better results than monocular used in conection with the observers better eye" for visual acuity; that the twilight modification of vision with respect to visual acuity showed better vision for the binoculars, other things being equal; that "the stereoscopic effect plays a distinct, perhaps very important, part in ordinary vision in localizing objects as to distance"; and finally that "in the hands of not very highly experienced observers the binocular performs slightly better than the monocular." Another investigation[216] of binoculars covered the effect of various factors when the instruments are used at night. The adaptation of the eye, visibility of a source of variable brightness at different distances, the effect of background, diffuse light, size of field, etc., were among the subjects studied. A power of 5 or 6 with an exit pupil of 7 to 8 mm. (0.3 in.) was recommended as probably best for a hand instrument; while a power of 10 might be used for a stand instrument.

Visibility.—A scale of surface visibility[217] used during the war by the French was adopted with slight modifications by the Meteorological Section of the United States Signal Corps. In January 1919, it was superseded by the following scale which has been adopted by the Meteorological Office of London, the Admiralty Meteorological Service, the Meteorological Service, Royal Air Force, and the French Army Meteorological Service.

Visibility Scale.	Objects not visible in good daylight beyond	
	Meters	Miles
0. Very bad	200	0.1
1. Bad	500	.3
2. Very poor	1,000	.6
3. Poor	2,000	1.2
4. Indifferent, ordinary	4,000	2.5
5. Fair	7,000	4.3
6. Good, above ordinary	12,000	7.5
7. Very good, unusual	20,000	12.4
8. Exceptionally good	30,000	18.6
9. No report (for telegraphic use)	—	—
	Objects visible in good daylight beyond	
10. "V" of Beaufort notation	30,000	18.6

It has been suggested that typical objects such as barns, houses, etc., chosen for measuring visibility should subtend a vertical angle of 10′ and a horizontal angle of 2.5′. Objections to this

[216] *Sci. Abs.* (A), June 30, 1919, p. 274.
[217] *Sci. Amer. Supp.*, Nov. 8, 1919, p. 279.

type of object may be met by the use of a target placed at 200 m. (66 ft.) from the point of observation and viewed through smoked glasses. Experiments are under way to develop and to establish a standard visibility measurer in which a screened light is viewed through glasses of different opaqueness.

Among the methods of testing the limits of vision[218] is that of finding the distance (or the angular diameter of the eye) at which one can distinguish a dark line against a light background. Experiments on a light line against a dark background using a group of riflemen experienced in close observation, gave results in good agreement with those of the condition first mentioned. Using a background of black paper (coefficient 0.0045) white thread (0.008″ in diameter) and drawn tungsten wire, (0.005″ in diameter) under bright skylight and also under moderately bright sunshine, the wire was visible by one observer at a distance of 150 ft. (45.7 m.) and by others only at 100 ft. (30.5 m.). The thread, which was much brighter than the wire began to be lost in parts at 200 ft. (61 m.) but in sunshine held indistinctly but unmistakably up to 300 ft. (91.5 m.). When the sun disappeared the thread was lost at 200 ft. (61 m.). The brightness contrast between thread and background was about 16:1.

In using searchlights[220] to detect objects such as men, cannon, aeroplanes, etc., the object illuminated must be seen in contrast to the diffused light in the path of the beam, or in contrast to other diffused light. Or in other words, the brightness of the beam determines what the brightness of the target must be to have it visible. Experiments on this subject have been made which yielded data for two observers on the relation between visual angle, contrast and field brightness, but indicated that for practical application, mean values from a large number of observers should be employed. Reference may be made to the 1919 report[219] of the Standards Committee on Visual Sensitometry of the Optical Society of America.

Visual Response.—New empirical data have been obtained[221] by observation, and measurements made which seem to indicate the operation of the "all or none" neuro-muscular tissue law in visual response. Experiments on the time required for visual

[218] *Sci.*, Oct. 3, 1919, p. 331.
[219] *Jour. Op. Soc. of Amer.*, Mar., 1920, p. 55.
[220] *Sci. Paper*, B. S. No. 366, 1920.
[221] *Psychobiology*, May, 1919, p. 459.

response, under different distributions of brightness over the visual field, indicate[222] that if the surroundings are of the same order of brightness as the object under study, vision is more accurate and certain than when they are dark or considerably brighter. Also that "the matter of appropriate distribution of brightnesses would seem to be of greater importance than has been attributed to it by illuminating engineers."

The effect of intermittent light on the human eye has been the object of considerable study, but little has been done on the subject of the effect on organisms other than man. An investigation of the effect of intermittent light on the mourning-cloak butterfly whose reactions to light are fairly well known indicated, that, at certain flash-frequencies, the stimulating effect is greater than that of continuous light of equal illuminating power; for other flash-frequencies, less, and others, equal to that of continuous light. It was found also that the stimulating efficiency of intermittent light of relatively low flash-frequency depends on the ratio between the duration of the light periods and the dark periods.

Color.—The comparative effect of light from gas mantles,[223] having various proportions of ceria and thoria content, and from a kerosene flame, on the loss of efficiency and discomfort of a certain amount of eye work done under illumination by these sources, has been studied. The brightness of the test object was 0.0032 c. per sq. in. and of the reading page 0.0033 c. per sq. in. and the working distance was about 60 cm. (23.6 in.) The results indicated a progressively increasing loss of efficiency from the 2 per cent. ceria mantle and the kerosene flame which were about the same, down to the 0.25 per cent. ceria mantle. Or from the color standpoint seeing was more comfortable and efficient from the light under the 3 per cent. ceria mantle whose dominant color was given as "unsaturated, clear yellow," and the kerosene flame color, given as "orange yellow," than under light from the 0.25 per cent. ceria mantle whose color was described as bluish green. The influence of color upon mental efficiency and muscular facility[224] has been studied and the results seem to confirm

[222] *Psychobiology*, Apr., 1920, p. 137.
[223] *Amer. Jour. Ophthal.*, Jan., 1920, p. 21.
[224] *Am. Jour. of Phys. Optics*, Apr., 1920, p. 137.

the effective neutrality or equivalence of colors when considered as isolated factors of experience.

Further work on the chromatic sensitivity of the peripheral retina[225] has been directed to the subject of the absolute limits of color sensitivity and the effect of light intensity on the apparent limits. Among the results reported were that the far periphery of the retina is not blind but merely deficient in sensitivity to the red, blue and yellow, but for the observers tested, is blind to green; that a very great change in intensity is required to produce a detectable change in the apparent limits of sensitivity in the more remote parts of the retina. Work has also been done on the foveal adaptation to color.[226] From the experiments it was concluded that in general adaptation to direct sunlight, the fovea has a longer adaptation-time for color than any other part of the retina, and this apparently holds for all intensities, high, medium and low; that chroma is the principal determinant of the rate of adaptation, and intensity is a second factor; that there is no difference in the experienced course of adaptation between a surface color and a pure spectral color. The persistence[227] of vision for several colors within the cone whose semi-vertical angle is nearly 40 degrees has been measured, more than 100 points on the retina within this area being observed for each color used. The persistence was measured by observing the minimum speed at which a sectored disk could be driven without destroying the apparent continuity of the light. Results were obtained for one observer only who found for red light (0.668μ) the persistence of vision in the fovea was 0.0209 second. For any other part of the retina it was greater, increasing nearly in proportion to the distance from the fovea, reaching a maximum value of 0.109 second on the nasal side of the retina at about 38° from the fovea. Similar results were obtained for the yellow green (0.531μ).

Research work has been carried[228] out on the subject of discrimination of color by fish, to determine whether they can respond to differences in wave-length of light or only to differences in intensity of light. The results showed that both sunfish and horned dace discriminate light of longer wave-length from light of shorter wave-length and from white light.

[225] *Phy. Rev.*, Jan., 1920, p. 1.
[226] *Am. Jour. of Phys.*, Jan., 1920, p. 35.
[227] *Proc. Nat. Acad. of Sci.*, Apr., 1920, p. 221.
[228] *Behavior Monographs*, 4, No. 3, 1919.

LEGISLATION.

Codes.—The Committee on Lighting Legislation has been authorized to act for this Society in the matter of carrying out the revision and issuance of the Industrial Lighting Code under the method of procedure of the American Engineering Standards Committee.

The industrial lighting code on which so much work has been done in Ohio has finally been adopted[229] by the Industrial Commission of that state as a "guide for inspection" to be used by the factory inspectors of the Commission in issuing orders for the improvement of industrial lighting systems. A year's tryout is to be given the code before it is given the force of a general law, and an educational campaign is to be carried on by the Commission during this period. The code while following quite closely that of this Society differs chiefly in having an additional grade of one-half foot-candle minimum for very rough work, similar to the New York code, and in the omission of the rules for emergency lighting and switching apparatus. "White Way" lighting has been legally[230] recognized in Ohio by an act of legislature which permits municipalities to assess all or part of the costs of "White Way" lighting on the owners of abutting property.

The Wisconsin Industrial Lighting Code[231] was put into effect July 1 for all existing installations. Hitherto it has applied only to new installations. The Commission has stated that too shallow reflectors do not necessarily have to be replaced if the requirements are met by using bowl-frosted or bowl-enameled lamps or opal caps or shields. In Utah,[232] an industrial lighting code is being drafted and will be presented at the next session of the legislature.

The Industrial Accident Commission of California has issued new[233] "General Lighting Safety Orders", effective December 1, 1919. They are mandatory and prescribe the minimum quantity of light either natural or artificial which must be supplied in all enclosures, yards and passageways used by employees. Under "Natural Lighting" is specified that where used it shall be of twice the intensity given in the rule for artificial light, and that

[229] *Elec. Wld.*, June 19, 1920, p. 1416.
[230] *Elec. Rev.* (U. S.), Apr. 3, 1920, p. [illegible].
[231] *Elec. Wld.*, July 10, 1920, p. 91.
[232] *Elec. Wld.*, July 10, 1920, p. 96.
[233] *Jour. of Elec.*, Jan. 1, 1920, p. [illegible].

proper shades and awnings must be provided to protect workers from glare. For "Artificial Lighting" the foot-candle requirements range from a minimum of 0.02 required for roadways and yard thoroughfares to a maximum of 5 foot-candles for special cases of fine work, such as watchmaking, engraving, drafting, etc. All measurements are to be made on a standard photometer, certified by the Commission. Under the general laws of Oregon effective May 15, 1919, the Commissioner of Labor appointed[234] a Lighting Commission to draw up a Code of Industrial Lighting. This Code was drawn up in December 1919.

In December 1919 the New York State Department of Education officially recognized[235] the I. E. S. Code of Lighting School Buildings as a guide for the artificial lighting of school buildings in that state, and in Wisconsin, the Industrial Commission is now preparing a Code for the same purpose. At the request of the Commission, the I. E. S. appointed a representative to serve on the special committee that is preparing the Code.

A code for the illumination of interiors of buildings was presented[236] to the German Illuminating Engineering Society, in which values are prescribed from 1 lux to 50 lux (0.09 foot-candle to 4.5 foot-candles) as minima allowable for various conditions.

Vehicle Lighting.—A new statute on automobile lamps has been drafted by the Industrial Commission of Wisconsin,[237] and became effective[238] as a law, May 1st, 1920. After defining specific terms used in connection with the regulations for motor-vehicle headlights and other lights, the statute provides that "any automobile, motorcycle or other similar motor vehicle shall not be driven upon, or shall not occupy any public highway during the hours from thirty minutes after sunset to thirty minutes before sunrise, unless it displays lighted lamps of the specified size, type and number and equipped as required by these orders." It is further ordered that to eliminate dangerous glare or dazzle for headlights there shall be used a light of not more than 2400 candlepower, measured at a distance of 100 ft. (30.5 m.) in front

[234] TRANS. I. E. S., Dec. 30, 1919, p. 144.

[235] TRANS. I. E. S., Dec. 30, 1919, p. 144.

[236] *Zeit. f. Beleuch.*, Jan. 15, 1920, p. 1.

[237] *Elec. Rev.* (U. S.), Feb. 14, 1920, p. 281.

[238] *Wisconsin Motorist*, April and May, 1920.

of the vehicle and at a height of 60" (1.5 m.) above the surface on which the vehicle stands. When measured at a distance of 100 ft. (30.5 m.) in front, 7 ft. (2.1 m.) to the left and 60" (1.5 m.) above the surface the light shall not be greater than 800 candlepower. Such lights may be tinted but not red. On the other hand, minimum permissible road illumination is specified in a section which gives values the same as those included in the revised rules of the Committee on Automobile Headlight Specifications of this Society.[239] Specifications for the size of electric incandescent lamps, and for lights on vehicles standing at the curb, together with provisions for tail lights are included.

An amendment of the New York State Headlight Law was enacted in 1920 and provides (1) that every motor-car must be provided with an approved lens before a license is issued, and (2) lens must be approved in New York State before sale in this state. Automobile headlighting ordinances based upon the I. E. S. Model Headlight Law are now in effect in California, Connecticut, Maryland, New York and Pennsylvania.

Last winter the city of Phoenix, Arizona, adopted a headlight ordinance similar to the California Headlight Law. The Phoenix ordinance applies to about 50 per cent. of the total number of motor vehicles used in the state of Arizona.

In England,[240] the Ministry of Transport appointed a special Committee on the subject of vehicular lighting and to investigate the problem of glare from automobile headlights, and this Committee has made two interim reports. It recommends that the maximum candlepower per lamp should be 24 and the greatest diameter of lens 7 inches (17.8 cm.) as a temporary measure. The report states: "Every class of dazzle-reducing device now on the market here as well as in America and on the Continent is being exhaustively tested under normal road conditions and up to the present none has been found to combine the three prime essentials—absence of dazzle, adequate yield of light, and low cost." In addition the report covers the time of day at which lights should be turned on and the number of lights to be carried by various classes of vehicles.

239 TRANS. I. E. S., June 10, 1920, p. 281.

240 *Elec. Rev.* (Lond.), Apr. 24, 1920, p. 541.
Elec. Times, June 10, 1920, p. 472.

Supplementing a decree issued[241] August 17, 1919, the Italian Government has established minimum prices at which electric lamps can be sold. The effect is said to be the same as a 25 per cent. tax.

ILLUMINATING ENGINEERING.

Daylight Saving.—After the failure[242] of congressional action to maintain federal daylight saving, the National Daylight Saving Association decided August 22, 1919, to start a campaign to induce individual municipalities and states to make it locally operative. Since then a large number of cities and some states[243] have taken action to legalize daylight saving, particularly[244] in the eastern and central portions of the country. On the coast the contrary is true. Efforts to repeal the daylight saving law in New York[245] state failed. In Canada daylight-saving was adopted[246] throughout the province of Quebec. The French government[247] has adopted a program of daylight saving for two years, the clock being set back on February 15, during that period, and on March 15 in 1922, and thereafter. It is said that workmen in France are generally favorable to daylight saving. The Paris Gas Company saved 1 per cent. in coal or 15,000 tons, the Electric Company, 2,000 tons, and in general, the economy is put at 15 per cent. for electric light and 5 per cent. for gas. It has been computed that putting the clock ahead is equivalent to the arrival of 1,000 coal trains, each carrying 500 tons. Statistics from fifty-one German electricity concerns[248] supplying towns with an aggregate population of 600,000 indicate a difference in consumption during the summer months of 1916 from that for the corresponding months of 1915 amounting to 8.6 per cent. and this is attributed to daylight saving. Data obtained from bills[249] for nearly 100,000 consumers indicate a yearly monetary saving to the householder in the New England section of the United States, of approximately 3.5 per cent.

[241] *Elec. Rec.*, Apr., 1920, p. 260.
[242] *Elec. Wld.*, Aug. 30, 1919, p. 480.
[243] *Elec. Wld.*, Mar. 27, 1920, p. 745; Apr. 10, 1920, p. 857.
[244] *Elec. Wld.*, Apr. 17, 1920, p. 917; May 8, 1920, p. 1108.
[245] *Cleveland Plain Dealer*, Mar. 31, 1920, p. 16.
[246] *Elec. Rev.* (Lond.), Apr. 30, 1920, p. 562.
[247] *Elec. Wld.*, Feb. 21, 1920, p. 419.
[248] *Gas Jour.*, Feb. 10, 1920, p. 293.
[249] *Elec. Wld.*, Jan. 17, 1920, p. 170.

Restricted Lights.—As a result of the coal shortage during the last part of last year, the "lightless nights" were again[250] in evidence in many towns and cities of the Middle West. Indeed, war conditions were recalled[251] when the U. S. Fuel Administration issued an order on December 8th, effective on that day, giving the Railroad Administration authority to issue regulations relative to headlights and power from bituminous coal and coke. The use of ornamental lights, unnecessary street lights, sign and bill-boards lights was prohibited; cabarets, dance halls, etc., could be lighted only between the hours of 7 and 11 P. M., and stores were allowed to use light only six hours of the day. Manufacturing plants could use light only during the time prescribed for the use of power. In Paris, also, fuel saving[251] caused a renewal of regulations restricting external lighting of theatres, cinemas, etc.

Safety.—The California Industrial Accidents Commission[252] has published a chart giving a record of the number of accidents which occur in different months of the year. It shows that the number is very nearly proportional to the length of the daylight period.

Light Sources.—In this country two methods of producing light suitable for matching colors, or what has come to be called "artificial daylight," are at present in vogue. One for the most accurate color matching utilizes a high-intensity source, gas or electric, and a filter so made that the transmitted light has a spectral character sufficiently close to that of north sky light to make color matching identical under either. The other method utilizes an incandescent lamp whose bulb is colored so that the effective light is an approximation toward daylight. In England[253] a third method has come into some prominence in which the light from a lamp is thrown onto a shade, the surface of which contains a colored design so worked out that the reflected light approaches in spectral character light from the north sky. This reflected light is used for color matching. At first it was designed for use with a tungsten lamp, as the light source, but it has also been adapted[254] for use with a gas mantle. A seven-light gas fitting is

[250] *Elec. Wld.*, Nov. 1, 1919, p. 898.

[251] *Elec. Wld.*, Nov. 29, 1920, p. 1026.

[252] *Ill. Eng.*, Oct., 1919, p. 285.

[253] *Elec. Rev.* (Lond.), Dec. 12, 1919, p. 714.

[254] *Gas Jour.*, June 8, 1920, p. 631.

used and the coloring of the shade has ben altered to conform to the spectral distribution of the light from the mantle.

The use of artificial light in place of sunlight for fading tests of paints, pigments, silks, dyes, etc., has proved so satisfactory that an instrument has been worked out[255] for this purpose. It provides for forty identical tests at the same time.

A description has been given[256] of the three general classes of illuminating devices, rifle lights, illuminating drop bombs and illuminating shells, used by the United States and Allied armies during the war.

In the Progress Report for 1917 reference was made to a study of light production by the Japanese cypridina hilgendorfi. Further work on these crustaceans[257] by another experimenter gave results which have been interpreted to confirm the luciferin-luciferase theory, rather than the older photophelein-photogenin theory. A further conclusion that oxygen is not necessary for the production of light was later challenged[258] and additional experiments undertaken to prove the necessity of oxygen in all such bio-chemical light production. More study has been given[259] to the subject of synchronous flashing of fireflies. The results led to the conclusion that the flashing appears to be synchronous because for any individual the flashing is rythmical, the interval between flashes being a function of temperature and the rate of flashing varying between 8 and 16 per minute between 19° and 29° C. for the normal mating fireflies examined. Where a number of fireflies are together, undisturbed and in the same temperature air strata it is not surprising that enough flashes would have the same interval to show the synchronous effect.

Action of Light.—In Hawaii[260] interesting experiments have been made to find out the effect of light from the quartz mercury arc lamp on growing plants of bananas, pineapples and sugar cane. Normal sugar cane kept in the dark grew, but became pale. On exposure to sunlight no effect was found, but two and a half hours under the mercury lamp made them turn green. Three other lots of sugar cane were grown; one under colored glass, the

[255] *Elec. Rec.*, July, 1920, p. 23.
[256] *Sci. Amer. Supp.*, Aug. 23, 1919, p. 114.
[257] *Am. Jour. of Phys.*, Jan. 1, 1920, p. 544.
[258] *Am. Jour. of Phys.*, Apr. 1, 1920, p. 580.
[259] *Am. Jour. of Phys.*, Apr., 1920, p. 536.
[260] *Elec. Rev.* (U. S.), Sept. 27, 1919, p. 532.

second in normal sunlight, the third exposed to both sunlight and the light from the quartz lamp. The second gave 30 per cent. more sugar than the first and the third 38 per cent. more than the first. Riper and superior fruit was obtained in the case of pineapples subjected to the quartz lamp light 40 minutes every morning and the same result was found with bananas, while cut banana leaves and stalks kept fresh in water for two weeks after being submitted to the mercury lamp radiation, where, without this treatment they faded in one week. Experiments were also made with arc lamps whose carbons were impregnated with various salts. The results are attributed to the action of ultra-violet radiation. (It should be noted that in apparently all cases visible radiation was also present and hence what occurred might be due to both or either in the presence of the other.)

Experiments by the Bureau of Plant Industry[261] indicate that it is possible for plants to have too many hours of exposure to daylight as compared with the hours of darkness. "Too long a day as well as too short a day will prevent many kinds of plants from ever reaching their stage of flowering and fruiting." Results in the greenhouse showed that the flowering and fruiting period of practically any plant can be made to occur at any time of year by darkening the greenhouse in the morning and evening if the day is too long, or by providing artificial light if the day is too short. By using darkened chambers to shorten the period of light, and artificial light to extend it, it has been found possible to shorten the life cycle of plants so they would flower and fruit twice in one season. It has been concluded that cc. the length of the day . . . . is the most potent factor in determining the relative proportions between the vegetative and fruiting parts of many crop plants."

An investigation[262] has been carried out to determine the minimum time required by plant leaves to reach the maximum of greenness when exposed to light. Tests on a number of different plants show that in no case was the maximum greenness reached in less than twelve hours of illumination.

A method has been worked out[263] for getting numerical values of the true hiding power of white pigments and paints where by

[261] *Sci. Amer.*, June 5, 1920, p. 621.
[262] *Comptes Rendus*, Mar. 22, 1920, p. 711.
[263] *Jour. Frank. Inst.*, Nov., 1919, p. 671.

the hiding power is meant the ability of paint "to obliterate beyond recognition any background upon which it may be spread." It is numerically expressed in the case of pigments by the number of square centimeters of surface covered and hidden, by 1 gram of the material. For paint the number of square feet which one gallon of paint will cover and hide, is taken as the measure. The measuring apparatus consists of two pieces of plate glass, having one surface optically flat and in the lower side of which is cut a groove. A flat piece of steel on the under side of the upper glass serves to make a wedge-shaped space between the two pieces of glass which is filled with the paint or pigment under test. The pieces are moved with respect to each other until one edge of the groove disappears. The results for some pigments and paints are given in the table.

Pigment	Grs. pigment / grs. oil	Hiding-power pigment cm² / gr.	Hiding-power paint sq. ft. / gal.
1. Sublimed white lead	7 : 3	26	172
2. Basic carbonate white lead	7 : 3	36	243
3. Lithopone	4 : 3	51	190
4. Titanox	3 : 4	58	132
5. Zinc oxide (leaded)	1 : 1	59	194
6. Zinc oxide (pure)	3 : 4	57	145
7. Zinc oxide plus trace of lampblack	3 : 4	190	486

A comparison of the results by using the instrument with those by actual painting showed essential agreement. Data have also been published[264] on the reflection factors of a large number of paints of the type used for interior walls and ceilings.

Spectral transmission data[265] were obtained during the war and published on a large number of glasses used in goggles for the purpose of improving visibility, detecting camouflage, etc., dyed gelatine or celluloid between glass was used to cut out blue haze or brilliant glare, and dichromatic screens with the two colors transmitted approximately equal in intensity were used to detect camouflage. In recent years, methods of chemical analysis[266] have been greatly extended through the application of such phenomena as ionic deflection, X-rays, etc. A new method proposes the employment of the visible fluorescence excited in so many

[264] *Elec. Wld.*, Aug. 16, 1919, p. 363.

[265] *Phys. Rev.*, Sept., 1919, p. 261.

[266] *Jour. Amer. Chem. Soc.*, July, 1920, p. 1350.

substances, for their quantitative determination. The procedure is analogous to colorimetry, involves a modification of reflectometry and is said to have a sensitiveness of the same order of magnitude as these two methods of chemical microanalysis.

Photography.—Considerable attention in photography has been given in recent years to the development of cameras for very brief exposures. A high-speed multi-exposure camera of this type, has been designed[267] for studying the arc phenomena of switches, circuit breakers, comutators, etc. It is made up of twenty-two different lenses mounted staggered in circles about the central shaft which carries a light aluminum disk shutter with radial slots exposing the lenses in sequence. At a shutter speed of 10,000 r. p. m. the exposure rate was 2,600 per second. Another camera,[268] employing the electric spark principle, has made it possible to register moving picture images of the frequency of 20,000 per second. In this arrangement there is a continuous movie film illuminated by the sparks produced by the discharge of a Leyden jar, continuously recharged. The regularity of the discharge is secured by a vigorous blowing of the sparks. The apparatus has been used to photograph moving bullets.

A new sensitometer[269] for determining the value of material used on a photographic plate has been developed, of the class where the intensity of illumination is kept constant and the time of exposure made variable and continuous. A thin metal plate is used in which are cut slots or lengths proportional to the exposures which it is desired to impress on the sensitive material. The plate is then moved across the surface of the material with a uniform speed, or in another type of the same instrument in a discontinuous manner. It is claimed that the results obtained are more satisfactory than those obtained with the sector-wheel type of sensitometer. During the war, the United States Bureau of Chemistry undertook for the Bureau of Aircraft Production the preparation of photo-sensitizing dyes of all the recognized types useful in photographic color work. In February of this year,[270] the Bureau announced that this work had met with suc-

[267] *Elec. Jour.*, Dec., 1919, p. 509.
[268] *Sci. Amer. Monthly*, Mar., 1920, p. 217.
[269] *Jour. Frank. Inst.*, Mar., 1920, p. 300.
[270] *Sci.*, Feb. 20, 1920, p. 187.

cess and that it was ready to place its experiments at the disposal of any manufacturer, for the American market, of these photographic aids.

Societies.—Reference should be made to the three simultaneous conventions[271] in February of those interested in the manufacture of lighting fixtures and glassware, comprising the National Council of Lighting Fixture Manufacturers, the Lighting Fixture Dealers Society of America and the Illuminating Glassware Guild. Other reference will be found under the caption "Fixtures." In Glasgow, Scotland, a local society called the Glasgow Lighting Association has been formed.[272] A syllabus of papers to be presented in 1920 includes one on photometry, one on glassware and one on incandescent gas mantles.

The Japanese Illuminating Engineering Society is progressing,[273] and regularly publishing transactions. Among the subjects dealt with may be mentioned: Artistic Aspects of Lighting Fixtures; Distribution Curves; War and Illumination; Searchlights; Spherical Reduction Factors; Electric Lamp Standardization. The German Illuminating Engineering Society[274] has also continued its work and it is interesting to note that they have "taken a leaf from the book" of this Society and our English cousins, and arranged for an elementary course of lectures on illuminating engineering. In the Report of their Committee on "Glare and Shadow Contrasts" two limits are proposed as regards brightness, 0.75 H. C. per sq. cm., (apparently for objects in the direct field of vision) and 5 H. C. per sq. sm. for sources placed outside an angle of 30° to the normal direction of view. The Council of the German Society consists of twenty-four members, six of whom are members of the electrical engineering society and six members of the gas institute.

BOOKS.

"The Physiology of Vision with Special Reference to Color Blindness," Dr. F. W. Eldridge-Green, (G. Bell and Son, LTD.) London, 1920, pp. XII + 280.

"Electric Lighting," Ward Harrison, (American Technical Society) Chicago, 1920, 202 pp. Introduction, contents and index.

271 *Elec. Merch.*, Jan., 1920, p. 19.
272 *Ill. Eng.*, Mar., 1920, p. 108.
273 *Ill. Eng.*, Sept., 1919, p. 268.
274 *Ill. Eng.*, Oct., 1919, p. 294.

"Von Kienspan bis zur Quecksilber-Dampf-lampe und dem Tesla-Licht,"[275] A. Forster, (R. Dech and Co.) Bern, Switzerland, 1920.

"Artificial Light — Its Influence upon Civilization," M. Luckiesh, (The Century Co.) New York, 1920; 358 pp., 52 illus., introduction and index.

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"El Arte de la Iluminacion,"[276] H. M. Levylier, (Centro Estudiantes de Ingenieria), Buenos Aires; 250 pp.

"Electric Lighting in the Home,"[277] Leon Gaster and J. S. Dow, (Sir Isaac Pitman and Sons, LTD.), London, 1920, 31 pp.

"Trattato di Fotometria,"[278] A. Coacci, (Ulrico Hoepli) Milan; 247 pp.

[275] *Licht u. Lampe,* May 6, 1920, p. 200.

[276] *Rev. Gen. d'Elec.,* Jan. 31, 1920, p. 146.

[277] *Ill. Eng.,* Feb., 1920, p. 60.

[278] *Rev. Gen. d'Elec.,* Apr. 24, 1920, p. 544.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XV | NOVEMBER 20, 1920 | NO. 8

PRESIDENTIAL ADDRESS.*

S. E. DOANE.

The presidential address of my predecessors have been on varied topics. Each address bears evidence that the subject discussed was one which had been very much in the author's mind during his administration. The problems with which your executive deals each year are largely beyond his control and result from conditions so general that each administration has small opportunity to do what it would like to do were it entirely free. This was particularly true of the war time administrations. My administration has been the first for a number of years in which conditions have made it possible to lay out a considerable amount of constructive work along the lines of normal activity of this Society.

The administrative period of one year is too short a time to permit a council and an executive to formulate new plans and to carry them through to a complete conclusion. In the past year, we have attempted to build a foundation for future progress along the lines so wisely laid down by the founders of our Society and carried on by the preceding administrations.

The great function of our Society is educational. To a considerable extent we have been obliged in the past to gather together the material which we hoped would be accepted by science and industry as authoritative pronouncement around which progress in illumination would be made. I have been gratified beyond measure to find to what extent this Society is accepted for just what it aims to be — a scientific society without commercial leanings or connections.

* Presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland Ohio.

The year which has just passed has been marked by a public appreciation of the need for greater knowledge of illumination. The report of our Secretary will tell you how our committees have functioned and will detail the work they have done. It is my purpose in this address to review more broadly the course which this Society is following and perforce must follow in the light of our present knowledge and announced aims.

Our problem for the past year, for the ensuing year and, I trust, for many years to come, will be to find new ways or to make larger use of the old ways of wielding a greater influence, of increasing our knowledge and of furthering its dissemination. As we succeed in these aims, we shall find our membership increasing and our influence correspondingly growing.

This society is of use to a man from two entirely different standpoints. It is of use to a man when he needs assistance. It is of use to a man when he wishes to increase his usefulness to his fellow-men.

Your Council has agreed during the past year to an extension of our educational work in a way which will be of benefit to both these phases of a man's need. In order to increase our value to the man who needs assistance, we must have that assistance in such shape that it is readily available. Now, since we are a scientific society whose very considerable function is educational, it is obvious that such assistance must be educational assistance.

To the man who would help his fellow men, this Society offers the opportunity of preparing the material which should be used in our educational effort. In practice, of course, no one of us falls wholly in either class. The man who seeks information to-day might furnish it to-morrow. The vehicle of usefulness or assistance is naturally the publications of the Society. Our TRANSACTIONS have fulfilled a most useful function but in the judgment of your Council and your President, the time has come when their form should be changed and when we should organize for regularly issuing material in other forms. The papers of this Convention, following the precedent of previous years, will be fed out to you through the TRANSACTIONS throughout the succeeding months. This is too slow a process. I believe that our papers should be bound and given to the members at the earliest possible date following the convention.

I believe that the TRANSACTIONS should be used as vehicles for the conveyance of new ideas, new papers, new facts, new material of all kinds and also for the discussion of this material. They should lead up to the issue on the part of the Society of a new series of publications which will partake of the nature of bulletins or symposiums or exhaustive compilations on a subject.

It is obvious that such a program requires money and that without additional finances we could not do justice to this conception of our responsibility. It has been the good fortune of your retiring President, through his business connections and acquaintances, to so present the possibility of good to result from the support of such a program that sufficient assurance has been received to warrant him in announcing that barring the usual exceptions for the unforeseen, it is expected that your Society will be able throughout the ensuing year to issue a series of bulletins on various subjects which will be compiled by the authorities on those subjects and which when issued will be sold to, and used by, manufacturing companies, central stations, sales organizations, and others. It is intended that the Society shall itself make all these reprints for a price greater than the cost so that the bulletins will be self-supporting and will contribute a sufficient sum to pay the necessary overhead which would be needed to take care of the program. I expect as a result of this agreement and program that we shall be able to furnish the educational institutions of this country, manufacturing companies, sales organizations, central stations, and all others who must needs gather such information and distribute it to their organizations and to their trade the best record of information and procedure on the subjects coming within our scope.

The Educational Committee has done splendid work throughout the past year and has done so much preparatory work that it will show greater results throughout the ensuing year toward getting courses on illumination established in our colleges, high schools, grade schools, correspondence schools, and in the commercial and other societies and associations.

Several of the large manufacturing companies now publishing their own technical bulletins on general illumination subjects have agreed to present these compilations as papers to the Illuminating Engineering Society for their discussion, committee revision, editing, and acceptance, so that the manufacturing company who

had in mind using such a bulletin, instead of writing it itself and sending it out to the trade, would write it exactly as if it had intended to send it to the trade, and would then submit it to the Society, as a suggestion for a bulletin. Through the proceedings and discussions of the Society, the material would be referred to a Committee on Compilation and Editing who would whip it into shape and put it out as a bulletin to the membership of this Society and reprint it, at a price in excess of the cost, for the manufacturer who employed the man who primarily wrote it, for others engaged in similar work, and anyone else in the industry who could use such a publication in its organization and with its trade.

It is my belief that such an opportunity to increase our usefulness would attract the two classes of men to whom I have referred — first, the class which wishes assistance, and second, the class which is willing to render assistance — and that we have thus set the stage for a membership increase.

In the course of my work on the educational function of our Society, I have run into a situation which I wish to present to you for your very serious consideration. The sequence of thought is obvious.

First, we have succeeded in demonstrating to the country the need for better illumination.

Second, the acceptance of this view has raised the need for an augmented effort along educational lines.

Third, when we review the field to fulfill this need, we find another matter of the greatest seriousness which is the need for financial recognition of the men who are engaged in scientific work outside of the strictly industrial field. In this class fall the teachers of our schools and the scientists in government employ.

The exodus of educators from our colleges and universities and of scientists from governmental bureaus has reached truly serious proportions. These men are finding employment as specialists in large organizations which do not hesitate to pay substantially more than most educational and governmental institutions find it possible to offer.

The true scientist is a peculiar individual in certain respects. His love for his work is second only to his love for his family and his home. Money seems to have small attraction for him as long as he is able to live with a fair degree of comfort from day to

day. The pleasures that most of us find away from our desks, outside the confines of our daily problems, the scientist finds in fullest measure deep in the intricate details of his work.

In the past few years, however, the cost of living has intruded upon his consciousness. It has insisted upon recognition. In the cases of many men, wedded to their work, it has presented nothing short of an ultimatum. The result has been that men who have refused to consider really handsome offers from industrial plants in the past because of their love for the work they were engaged in, have been forced at last to accept outside offers in order that they and their families might live decently and comfortably, and lay a little aside for the proverbial rainy day.

I understand that certain educational institutions have endeavored to adjust their salary scales sufficiently to retain the men who act as the educators of your children and of my children. Undoubtedly others will follow suit. As educated men ourselves, we cannot afford to leave the future instruction of our young manhood and womanhood to men not in industry because they are not competent to be in industry.

I am speaking, however, not in favor of educators as such alone. We are, I am sure, in grave danger of seeing the scientific bureaus of the Government completely disorganized. It used to be that a man fresh from commencement felt it an honor to obtain employment with, say, the Bureau of Standards. Now, I am informed, this Bureau is glad to take almost any man that applies, and this condition is typical of most if not all Government scientific organizations.

I need not argue with this Society the value of the scientific work of the Government. We know that a discovery which changes the cost of manufacturing a dyestuff from several dollars a pound to as many cents a pound is important not only to manufacturers but each one of us as individuals. We know that research that results in eradicating cholera in hogs means something to us as well as many millions of dollars to the farmer. We are glad to agree that the discovery that the common garden slug was three times as sensitive as man to poison gases, which saved incalculable lives for the allies in the recent war, affects each one of us as well as the men who wore the masks. Yet the facts of the case are that men who have labored for years in the interest

of science and who have planned to spend their lives in the work are now being forced to accept employment with private corporations whose salary scales are in accord with the present costs of living.

Let me present for your consideration a few facts as gathered very recently by one of my assistants. One of the important Government scientific divisions operating in Washington is divided into 14 sections, each of which is now composed of from 2 to 19 men. The section composed of 2 men has lost, since July 1917, 9 men excluding temporary help. The man in charge has been with the Division seven years; his assistant two years. In the section employing at present 19 men, one has remained thirteen years; 4 have three years' experience; 5, two years'; 3, one year's; the remaining 6 have served a matter of weeks or months only. Nine of these 19 men were expected to leave in September. This particular section has lost 29 men since July 1917; among those who have gone was one who has served 12 years at this work. In another section doing very important testing work, — work which is not being handled at this time by any private laboratory — there is left 1 man who has served two years and 4 men who served less than one year. Twelve men have left in the last three years, one who had given 16 years to the work.

The reason these men are leaving is, as I have stated, one of insufficient immediate salary and small prospects for future increases. To substantiate this statement, I quote from the annual report of the Secretary of Commerce for 1919, and I ask you to remember that conditions have been steadily getting worse since this report was published.

"During the last two years the Bureau of Standards has lost nearly or quite 50 per cent. of its technical staff. This applies to all grades of trained scientific and technical men, but is especially true of the leaders in specific lines. The salaries of these men in the laboratories of the industries or in consultation work are usually double those which the Bureau of Standards is permitted to pay. To make this entirely clear, a table is given below in which the names are represented by letters, stating actual cases of experts who have left the service for other salaries and giving the salaries paid elsewhere.

Name	Title at Bureau	Bureau Salary	Salary Outside	Title outside
A	Chief of paper section.	$2,700	$7,200	Director of department of technical control of largest paper concern in the country.
B	Senior associate physicist in metallurgical division.	3,300	5,000	Research metallurgist in large metal corporation.
C	Electrical engineer.	3,300	4,500 and promise.	Electrical engineer.
D	Chief of textile section.	2,500	About double.	Consulting textile expert.
E	Associate physicist, in charge paper laboratory.	2,500	Nearly double.	Head of research utilization and new developments in a large paper concern, operating 12 mills.
F	Chief, magnetic laboratory.	2,500	Two or three times more.[1]	Consulting expert.
G	Gas engineer.	2,520	3,300	gas engineer in large gas corporation.

"The following table gives cases in which private firms have offered the technical experts of the Bureau of Standards higher salaries than those they are receiving. In some of these cases the experts were asked by outside employers to name their own price, yet they have remained at the Bureau of Standards at a personal sacrifice, which it is wholly unfair as well as unwise to ask them longer to continue.

Name	Title at Bureau	Bureau Salary	Salary Outside	Title outside
H	Chief, division of ceramics and optical glass.	$4,800	$10,000	Ceramics chief.
I	Physicist and chief of the metallurgical division.	4,000	7,500	Scientific metallurgist in charge of American end of large metal corporation.
J	Optical-glass expert.	2,500	5,000	Technical expert in optical glass factory.
K	Associate physicist and metallographist.	3,000	[2] 5,000	Chief of gauge manufacture in large industrial concern.

[1] Refused outside offer of $7,500.

[2] Contract arranges for increase; base salary is guaranteed.

"The above examples are chosen from the higher grades, but facts in the same proportion exist in all the grades of the scientific and technical staff. If this process is to continue, many lines of the bureau's investigational work will have to be abandoned. The best we can hope to do at the low salaries now provided is to maintain a few untrained men for routine and testing work, and even this will suffer for lack of proper supervision.

"The Bureau of Standards has more than 100 specialized lines of scientific and technical work. Each demands an expert of experience and ability, able to plan and supervise research and testing of a superior grade. The bureau cannot pay the salaries demanded by men who are already trained and have the requisite administrative experience, since there are but 30 positions in the grades from $3,000 to $3,500 per annum, inclusive.

"A critical situation, therefore, arises, since, even when the bureau trains competent men and fits them to become chiefs of sections, the industries pick them off as fast as they become thoroughly competent. The reason is solely the low salaries the bureau is able to pay and (even at such salaries) the relatively small number of good positions compared with the number of specialized fields in the bureau. The case becomes even more serious when it is remembered that the Bureau of Standards is expected to be the leader in each of these specialized fields of scientific and technical work."

The scientific Bureaus of the Government are run on appropriations determined by Congress. This body is confronted with the problem of keeping taxes down on the one hand and maintaining necessary governmental activities on the other. Certain lines of these activities naturally do not permit of appropriation shaving; their necessity appears so obvious that Congress has no choice but to set aside handsome amounts for their maintenance. By the time these activities are taken care of, vast sums of money have been expended, and when the scientific Bureaus come up for consideration, their appropriations are pared to the bone to keep the total as small as possible.

We should not blame Congress unjustly for their failure to grant adequate appropriations for scientific work. The facts of the case are that the public never thinks of what the elimination of waste in a manufacturing process with which he is in nowise

familiar means to him; he is not particularly interested in the introduction of a wheat into the United States which brings the farmer close to a hundred million dollars a year; how does the discovery that certain bacteria can change cane sugar into acetic acid affect him as an individual ? The work of the scientist has not been advertised. It is not appreciated by Tom, Dick and Harry. If you and I can make it a point to drop a word here and there as to what excellent work government scientists are doing; if we can go further and point out how this work affects the welfare of each individual in the nation; if we can go still further and say that it now costs each one of us just about fifty cents a year, or one per cent. of the $50 per capita which the National Budget represents, to support these research, education, and development activities of the government; if we can advertise, if you please, this scientific work, I believe that we will find the people as a whole are willing to invest a trifle more heavily in it. With public opinion strongly on their side, the men who have been so loyally sticking to their ships will have no trouble in getting adequate appropriations; the laws which prevent the payment of a salary sufficient to keep the kind of men scientific research requires will be set aside, and a splendid impetus will be given to that work which must at all times lead the progress of society. This same public opinion will assure to the nation the means of retaining in office the men and women who wield so great an influence on the coming generation — the educators in our schools, colleges, and universities.

EXPERIENCE ON GENERAL PERSHING'S STAFF.*

PRESIDENT GEO. H. HARRIES.

On the bulletin board is the announcement that I am to talk about "Experiences in the Army of Occupation." I would like to amend the title. We who went into interior Germany and then traversed pretty much all of Europe, prided ourselves on not being of the Army of Occupation. We had nothing to do with it. It had no jurisdiction over us. We belonged to General Pershing's staff and Marshall Foch's. We were the advance guard and we declined to look except with condescension upon the man who was merely in the Army of Occupation. He was an armed man; he had numbers and military strength.

Our expedition went in the beginning of December, 1918; two husky lieutenants and two ultra-husky orderlies. We left all of our armament in France. We decided that if we couldn't capture Berlin with our bare hands, we wouldn't do it at all.

What to talk about is a problem, for there is so much of material. I haven't any set speeches. I never did have. It occurs to me that inasmuch as I have talked of Germany last year to the Illuminating Engineering Society and in half a dozen other places, that there may be some duplication, but there will hardly be enough of that to be important.

The thing that strikes me as of the utmost importance, not merely during our time in Germany, but important through the years to come, is Germany's failure to understand other than German minds. I am led to that probably by the superman theory which is if other people do not think as Germany does, their thoughts are not worthy of consideration.

How easily the Germans went wrong! They went wrong as to Belgium; their belief as to Belgium's non-interference with an invading army. They were wrong as to England's attitude; they never believed England would go to war for the sake of a "scrap of paper." They were wrong as to the decadence of France. One of the German general staff, two years before the war, spoke to me of the French Army as the "shell of a decaying egg."

* Presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920.

We know how France proved up. I wonder if all of us do know just what she did. I served with the French Army. I was in Petain's army at Verdun, and I saw—there's no use trying to tell it. One can't begin to describe it. But think of France and her population with a million five hundred thousand men killed and more than a million others totally disabled, never to be of any physical use to anybody during the remainder of their shattered lives. Think of the Nineteenth Breton Infantry recruited twenty-two times during the course of the war; two officers and five enlisted men surviving of the original regiment, and all of them disabled. Germany's guess on the French Army was very much off.

Then as to ourselves from the German point of view. We were commercial, strictly commercial; we were worshippers of the dollar. I heard that expression many times. Our symbol was the Golden Calf. Militarily, we were without preparation, wholly unready. Nationally, we were soft. Then when the news got across that we were really trying to do something in the way of assembling an army, Germany said, "Well, suppose they do. They can't get them over."

Then when they found we were beginning to get over, they said, "Well, it doesn't make any difference. The army doesn't amount to anything. They can't fight. They haven't had any experience."

They thought there were so many Germans in the United States who would sympathize with Germany that our army wouldn't really be a forceful body, whereas if you read the roster of the winners of Medals of Honor and Distinguished Service Crosses, you will find many a German name in a most conglomerate list. Foreign names but American hearts; a wonderful soldier combination.

I can see now two Italians (one tall, the other short) chasing a German officer; the finest foot-race that had been turned loose on the front for a long, long while. The little fellow finally sprang on the officer's back and bore him to the ground. It was a tremendous fight and had a great audience; an audience that forgot the war as it watched, and that cheered heartily when this little Italian came back with his big German officer.

The mental attitude of Germany on our neutrality and our sales of war material to France and Belgium and England was a most

remarkable one. When it was voiced to me by an officer of the Imperial Staff, I referred to the Boer War and to Germany's selling arms and sending instructors and helpers to Kruger, to which he responded, "Ah, but that was different," that was the only answer you could get whenever you produced a parallel; and go beyond it you couldn't.

Their psychology was deeply interesting. Almost immediately after we got into Berlin, I commenced to be besieged by young German officers, who seeing their careers "busted," desired to take service in the United States Army. That number increased to such an extent that I had to draft a form letter, one of which was handed an applicant or sent to him if he had applied by mail. There were hundreds. I think my record shows between six and seven hundred German officers who desired to serve in the Army of the United States.

I haven't heard of any of our officers offering to serve in the German Army. We may be psychologically wrong. Somebody is wrong.

The last one of these officers that I saw came with a letter of introduction from one of the greatest generals of Germany, and therefore, I saw him, a clean, fine youngster about twenty-four years of age, highly skilled, and he wanted to serve as an instructor in the United States Army. I tried to let him down easily, but it wasn't possible. Finally, I said, "Now, I am going to ask you a question which you don't have to answer. Give me a reason, if you will or can, why an army which is victorious should seek for instructors from among those who have been defeated?"

He clicked his heels, saluted and left me. There wasn't any answer.

Now, the same strain ran through most of our relations. Count von Bernstorff, much beloved in this country, lived in the hotel which was our headquarters. Seven times he attempted—mostly through newspaper men, once through a German officer and once through an employee of the hotel—to arrange an interview with me. He came to the conclusion that I was rather an uncouth person, because the last one who came to me and said that Count von Bernstorff wanted to see me, got this answer: "All right, let me know when he is coming. I want to meet him properly. I

want to have all the exits and doors wide open. Send him up." But he never came.

The German seems to have this same lack of reasoning throughout. They were going to send von Bernstorff to Versailles to sit in conference with the others. One of the government officials spoke of it to me confidentially at that time. I said, "What are you trying to do? Are you sending him to Versailles for the purpose of having the President of the United States and the members of our delegation rise and leave the hall?"

He said, "They wouldn't do that."

I said, "They haven't told me that, but unless my guess is all wrong, they will do that very thing."

They never imagined that there could be any feeling on the part of the United States and its representatives there against von Bernstorff; who hadn't done a thing in the world except try to blow up all there was in the United States, and to deceive us in every way possible.

Brockdorff-Rantzau himself, clever and capable, had this same weak spot. When the peace terms were made known I was in Paris. I tore back to Berlin because I felt quite sure that something would be doing as soon as the German people knew what the peace terms looked like. I had about eight hundred officers and men who were in detachments in forty Russian prison camps scattered all over Germany, two or three million dollars' worth of stores for the feeding of those prisoners, and I thought I would like to be there while whatever was going to happen was happening, and I had only reached Berlin when Von Brockdorff-Rantzau, who was chief of the German representation at Versailles, sent an interesting telegram to the German War Office.

I remember that telegram particularly. In effect it was as follows: "You will notify the Chief of the United States Military Commission that it is advisable that he, his officers and men shall wear civilian clothing because when the German people understand the terms of the treaty their wrath will probably be spent upon the American Commission."

An assistant chief of staff brought it to me, and I looked at him to see if he wasn't smiling. Many things are excusable when you smile. But he wasn't. He was intensely important, and I de-

layed speaking a little while, for my sense of humor was working.

He said, "Will there be an answer?"

I said, "Yes. Will you send the answer? I will dictate it to you."

I said, "Address it to Von Brockdorff-Rantzau at Versailles, and let it read as follows: 'The time has not yet come when any German can tell me what kind of clothes I am going to wear.'" That telegram was not sent.

I telephoned the Brockdorff-Rantzau suggestion to General Pershing at Spa. I thought he ought to have it because there was always the possibility that if, as the result of our not wearing civilian clothing, the contemplated thing happened and some of our men were killed in riotous proceedings, some Congressman would be asking General Pershing whether the lives of American soldiers were cheaper than civilian clothing. We have Congressmen who would ask just such foolish things.

General Pershing's response to the telegram, by wire, was this: "You will notify the German Government in no uncertain terms that it will be held to the strictest accountability for the lives and safety of the personnel of your Mission."

So I sent that around to the German War Office.

Later came the anticipated demonstrations. Nothing that is really worthwhile ever happens in Germany without a demonstration. The treaty news came in slowly. The government was letting it leak through a little at a time; trying to avoid the shock.

On the Tuesday after the peace terms were announced there was a demonstration. There were about fifty meetings of protest in Berlin. The bells would toll at four-thirty. At four-forty-five the bands would play and at five o'clock the orators would start. There were about ten of these meetings not far from the Reichstag and down the Tiergarten; through that general neighborhood. At six o'clock the meetings closed, and then the entire crowd would go home.

Incidentally, I should say that we had had prior experiences with demonstrations. It was the habit with certain and diverse elements (when they had nothing else to do) to come around in front of our quarters and to blow off polysyllabic steam. We wouldn't pay any attention to that, and the fact that we regarded

such performance as unimportant undoubtedly resulted in additional outbursts.

We lived up to what Marshal Petain said about the British soldier and the Yank. He said, "You know, the British soldier, when he goes into a strange town, why, he moves as though he owned the town; but the American, when he goes into a strange town, acts as though he didn't give a damn who owned the town."

They never quite understood our normal attitude. We didn't talk about it. Nobody put up the job. It was just the Yank. He had his views about the war and who won it, and, without being the least bit bumptious, he didn't allow anybody to walk on his toes.

About six o'clock this great multitude, all of what we called the Reichstag group, came under the Brandenburger Arch and commenced to talk. They abused the United States—I don't know but some of them who were historical students may have done it by states and territories in the order of their admission—the United States Government, in all its branches, up to and including the President of the United States, who was the special object of their ire.

Well, some of us didn't care much what they said. You see, we are non-partisan in the army, entirely non-partisan, so we objected officially to those epithets. For four hours that crowd continued. It just didn't do anything but yell and carry on, but in the least effective manner I ever saw in a mob. Oh, there were some efforts, yes, but the Government got scared and re-enforced its guard; gave us guards. We never asked for guards, we never wanted guards, but they sent a battalion around and developed about sixty machine guns, so the mob went home.

The next morning I sent for the assistant chief of staff; a very remarkable thing, if you stop to think of it. You push a button and when the aide comes, you say, "I want so-and-so, the assistant chief of staff," and he sends for the desired officer, who comes. I have sometimes thought that whatever we may have suffered, whatever the war had brought, still it was worth while, worth while. I look back to the days when I was a buck trooper, and say, "If I had never been paid a cent for the years of service, yet I would have felt repaid, because I had the opportunity of look-

ing the Imperial German General Staff in the eye and giving it orders."

One of my humorous personal staff said, "The General is the logical, if not the legal, successor to 'William the Last'," so you see how difficult it is after having been a king for nine months, to come here and be a plain, average man, afflicted with democracy and Republican doctrines. It is an awful fall.

So the summoned officer came, and after we had bowed and he had taken his seat, I said, "Do you know that your people are the damnedest fools in the world?" Well, he wasn't ready to concede that. He and I had a great deal of business with each other and came to know each other very well.

"Well," I said, "they are. Last night for four hours, eighty thousand fools, by and with the consent of the government, demonstrated in front of these quarters, and I object to it. I don't care what you do so long as you don't interfere with my work, but they made so much noise outside last night that it just interfered, and I object to it.

"We have had a lot of it though all the months past. It doesn't worry me, but to prove that you are fools, I'll tell you that during last night's ruction I dictated four closely written typewritten pages, legal cap, of a report for the President of the United States, and the officer took it out through the crowd. It is gone by this time, and probably on the wireless for Paris, and within an hour or two the President will have the whole thing.

"In that report are all the epithets we could hear and all of the epithets that were heard by my agents in the mob. We have given them in the original German and in literal translation so that the President will know the particular epithets which applied to him. You are depending upon him to help you. He is the one man in all the world whom you believe will assist you in ameliorating the peace terms, and yet your government permits this. How much do you suppose he is going to help you after he reads all that rot?"

Well, he conceded that if they weren't the *damnedest* fools, they were at least fools, and he said, "I will put a stop to it. There will be no more such assemblies."

That was Wednseday morning. Thursday morning there appeared in all the Berlin papers a proclamation, "No More Abuse of Americans;" they were under governmental protection under

the terms of the Armistice, and had to be respected. If they didn't respect them, something harsh—that was the term—was going to be done.

Thursday night, they had more meetings. Once more came the crowds at 6 o'clock. Facing our windows, each man, woman and child—there were children in that great mass—crouched down and looked up and hated us in perfect silence. It was almost a military organization, governed by a preparatory command: "Hate by sections," followed by the command of execution: "First Section, hate." When the first section had hated until it was tired or didn't have any more available hate, the second section marched up and hated us, and so it continued for three hours and a half, without a sound, not a word or a whisper—silence!

Do you get the psychology of people who do that? If it had been one of our mobs, or a French mob or an Irish or an English mob, there would not have been one stone left on another of that hotel. The Germans took it out Tuesday night in language and Thursday night in expression. A very remarkable people!

You recall that Brockdorff-Rantzau, in his speech at Versailles, did more damage to the German cause in that three-quarters of an hour than had been done since the war, because he delivered his speech in German, when he is one of the best French students of Europe. But his German pride made him do it in German, and he wasn't feeling very well, so he sat down. The German people got a lot of satisfaction out of that, that von Brockdorff-Rantzau sat down and talked to the peace conference just as the Kaiser would have done.

However, they make few errors as to their own psychology. Prior to the war, and during the war, the socialists were tame; most of them imperial socialists. Of course, there were a few who were advanced, but they were either at the stage where they wouldn't bother anybody else, or were getting out of Germany a little ahead of the police. The socialist body in the Reichstag was under the control of the Emperor. It always voted imperially right. It talked wrong, but voted right.

The job of the tame socialist in Germany was to make real socialists in other countries. They figured on that before the war. They thought that would be a very worth while thing. They came near to doing it in France, very near, indeed.

Now, we have a few ideas that are erroneous about the German people. One of them, which was probably inspired, had it that we are not at war with the German people; that was insisted upon. I don't know but a note or two, or three notes, were written with that sentiment embodied.

We conceded, however, that the great bankers and manufacturers and merchants were at war with us. They contributed very heavily, very heavily indeed, and had been promised large rewards, but the people, the average people, why, they were altogether innocent. We were not at war with them. We had quite a number of officers who played up and down the land, from Fiume in the west, through the Balkan countries, down to Constantinople, and everywhere through Germany. They were intelligence officers, gathering information. They asked of thousands of people of the peasant class and the small shop-keeper class, whether they had the war spirit or not. There wasn't any break in the reply, down to the last and least. The women were waiting for the jewelry and the silks which were coming from Paris, the clocks and the furniture and all the things that were desirable, the loot. Then loot was coming from London a little later—a little delay there between London and Paris—and ultimately, when we got into the game, from the United States. Forty acres and a mule wouldn't be anything to compare with what they would have when the German Army came over here.

Throughout the entire structure, they were at war, and there was as much of bitterness among the people whom we will call the lower classes, as much of bitterness against us, as was to be found in any other class.

They were very much surprised and shocked when, after the Armistice, the blockade was not immediately lifted. Also they expected vast shipments of food from the United States. Their understanding was—I don't know where they got it—that when the Armistice was signed, we were going to feed Germany. There wasn't any ill-will, said they; why should there be? Why shouldn't we be as friendly as we had been That was the common view and they never could understand why we didn't sympathize.

I could talk here for seven days, twelve hours a day, about Germany, but I have a limit; I *must* have a limit. I wonder if it

wouldn't be worth while to say something about Russia. Russia was one of my clients during the war. We had at one time about a million Russian prisoners to take care of.

We had gotten rid of the Serbs, Italians, Roumanians, and, of course, the British and ours and the French prisoners had been sent home. And speaking about captives, the Berliners gave us some great demonstrations in behalf of the prisoners held by the Allies. The German government put these things up. When the Sparticists were running Berlin, there were more demonstrations. In each case the authorities were all friendly to us. The Government couldn't be actively unfriendly, and the Sparticists didn't want to be. They both protected our hotel from time to time. When the government was in power it had a guard on duty, and when the Sparticists came along they did likewise. For two days when they didn't know which was which, they both posted guards. Finally, the Government won out, booted the Sparticists across the Linden, and took over the whole job. We were situated as was the nervous old gentleman in a wooden Pullman. He objected to it. He said that no first class railroad ran anything but steel Pullmans.

The porter tried to soothe him. "Mah deah suh, yo' is all right. Yo' is pe'fectly safe in dis heah cyah."

"Why so?"

"Because dere is a steel cyah ahead o' yo' an' a steel cyah behin' yo'."

The prisoner story is an interesting one. It is worthy of a two-hour lecture; the marvelous things that were done for the Russians and the great opportunity we lost. Eight hundred of our officers and men and more than a hundred American Red Cross workers were scattered through the camps. Together they cleaned up the typhus and all the other things common to such camps, fed and clothed the unfortunates and brought them back to a sense of manhood. They had been four years behind barbed wire, filthy and half starved; rationed on about a quart of cabbage soup in the morning and as much more at night with 235 grams of awful bread. The bread had 17 per cent. of sawdust in it to give it body. They hadn't anything else to make bulk so they put sawdust in, and that is what the Russians had lived on, with a little fish once, and perhaps twice in a week.

So we brought them back to life with the help of cigarettes and schools and games and outdoor work. We found priests and established churches; a church in each camp; a theater in each camp. We ran a theatrical circuit, had moving picture shows, took pictures everywhere and used up a lot of the reels we got from the A. E. F. We had shows all the time. We had real theaters, one- or two-act plays by the Russians, written by them and censored by us (because some of them were "red") and they and we would get into the game and present the plays. We raked the A. E. F. for mandolins and guitars, and later for brasses so the Russians could organize balaika orchestras. Then we taught them to play football and baseball. What more could you ask than that? What greater honor could come to any American soldier than to be able to say that he had taught Russians baseball?

So, I had a good deal of communication with Russia. It was not direct. We wouldn't do that, but nevertheless we had it, and to show you how deeply interested Russia is in the United States, I will relate one incident. When Ambassador Francis left Russia, he left behind him one of his force—a Mr. Kalamatiano—who was a Russian by birth, and a graduate of the University of Chicago. I don't know how he came to be left behind, but they imprisoned him at once. He remained in prison, and is still in prison. The State Department asked for his release, but could not get him out. So through German channels, Foreign Minister Tchitcherin was asked if he couldn't turn him loose. Tchitcherin said he couldn't do anything.

Finally it got to Lenine. We thought we had covered up our tracks because we had had the Germans ask for him. His radiogram was to Berlin: "Tell the Chief of the United States Military Mission in Berlin that he can have this prisoner if he will give me in exchange for him, Eugene Debs."

So you will see there is a piano wire leading from Lenine, whether he is in Petrograd or Moscow, and Eugene Debs, who is in the penitentiary in Atlanta. Only Lenine isn't in the penitentiary at his end of the wire, but the relationship of Debs and Lenine ought to be clear. It wouldn't do any harm to say that we knew, from the Russian end, of more than 270,000,000 rubles in money and jewelry being shipped to the United States for the purpose of raising hell. In that, Germany was a partner. One

of her most capable officers devoted himself to the conduct of a great bureau devoted to the job of seeing how much trouble could be made industrially and politically in the Allied Countries.

As to how much of German funds had been concealed in the United States prior to our entrance in the war, we can only guess, but a very large sum of money has been spent in stirring up labor troubles and in doing everything possible to interfere with the course of business in all of the Allied countries; and special stress has been laid on France, England and the United States. We have had more than our share of such funds as have been raised. There is no doubt about that at all. There is no use in lying to ourselves and saying it can't be. It is so, and has been so since the spring of 1919.

We are a little careless in these days, in spite of the example. We are a little bit careless about our own peace and sometimes we become highly inflamed and then have no particular value as reasoning people. We tremble, we are fearful as to what may happen if we talk overmuch about the red program, the Bolsheviki. There is no reason why we should be scared. There are enough left of the practically four million men who were in the service to ultimately take care of anything that comes along.

I am thinking about the temporary things; about what may happen before a clean-up. I saw three demonstrations in Berlin on one day—on a Sunday. I saw 800 Sparticists, all armed; 200 of them women, all armed—no mistake about the female of the species being deadlier than the male. They came up the Linden, and turned down the Wilhelmstrasse so they might parade past the Government offices. They had just gone when another demonstration came through the Brandenburg Arch and went also down the Wilhelmstrasse. They were the Independent Socialists, akin to Sparticists. There were 6,000 of them.

They barely had gone by when there came under the great arch the most wonderful succession of human waves I think any one could ever have seen, the bourgeoisie, the Social Democrats, the plain substantial business class, the merchants, the manufacturers, the solid element in any country, with their women-folk. They had banners and banners and banners, and they shouted and carried on "For God and home and native land." I was standing in the window looking at that outfit when they noted

my uniform and started to cheer the United States. I backed off. I thought it was time for me to be out of that picture. There were 250,000 people in that demonstration. Get the figures now; 800 Sparticists, to 6,000 of the Independent Socialists, who would support Sparticism; 250,000 in this other demonstration of good, law-abiding citizens; just as good as Germans could be.

You would have said that Sparticism wasn't a menace with all that great, loyal body in existence in the same city. It wasn't a week later when the Sparticists, by that time numbering 1,600, chased the 250,000 all over the territory until their tongues were hanging out so they stepped on them. The 1,600 knew what they were doing, what they were going to do, knew how to do it. The 250,000 were just as helpless as they could be, and they would have been just as helpless if there had been a million of them. There would have been that many more who didn't know what to do.

It is in the beginning of these movements that action is essential. If Berlin could have smashed the 800 or the 1,600 at once, if it could have been done immediately, why she wouldn't have had so many thousands of funerals as she had in January and March, and she wouldn't have lost so many countless millions of marks worth of property. They let it go too long.

Now, we might perhaps learn something from the Germans in that particular. It is a good scheme to put your fire out before more than one article of your furniture is destroyed. Later it may be very difficult or impossible.

So stand by for order and for law. Stand by for a police force that is worth while; stand by your national guard. It brought us 400,000 people when the war started; 400,000 men who volunteered. Stand by!

Incidentally, that Cleveland Battalion, which was in the 372d Infantry—my junior regiment—was all right. I am not inclined to favor the negro officers because they usually don't know enough. The men recognized that. I am for the black man and all he is entitled to. I have had black troops all through my life. I think of that glorious old Ninth Cavalry and the things it did with more pleasure than anything else I know of.

Negro soldiers are wonderful fighters, when they are led, but the negro trooper says of the negro officer, "Why, he is jus' a

niggah, jus' lak me. What do he know about it?" He may know, but the other fellow won't let him know, won't concede it. So we had a good many white officers thrown in there. We had to. Without such, the organization wasn't sound; wasn't fit to go to war. It might look well on the street, but it wasn't the stuff to fight with. The other regiment was all white officers. I want you to know that your Cleveland men did uncommonly well, in spite of the handicap imposed by some of the less capable colored officers. The 371st and 372d had their regimental colors Croix de Guerred by the French and there were in those two regiments a greater percentage of Distinguished Service Crosses and more Croix de Guerre than in any division of 30,000 men on the fighting line. You will concede that white men don't give decorations to the negroes unless they have done something, and when they gave to them in greater profusion than to any other brigade, it meant that they had done well.

What can we do? The war is still on and great disquiet at home. I have a ten thousand ton cargo of incident and suggestion and cannot possibly unload it now.

At Brest, three days after the Armistice was signed, one of my old negro sergeants was on duty with a labor battalion. Seeing one of his outfit leaning against a warehouse, he said, "Come here! Come here!"

"What fo' yo' want me, sergeant?"

"Ah want yo' to go to work."

"De war's over. What yo' want to keep us workin' now for?"

"Yo' come here. Ah want yo' to come here because ah want yo', an' ah want yo' to know when ah want yo' ah ain't wantin' much."

"Ah only enlisted fo' de war, an' de war is over."

"Niggah, yo' is jus' half right. Yo' enlisted fo' de war. De war is over, but when yo' enlisted, yo' also enlisted fo' de duration, and de duration have only jus' begun."

The duration is still with us. They signed an armistice between Poland and Russia recently, and not before about Tuesday or Wednesday next will there be another war. There is a little row between Poland and Lithuania; it may be bigger to-morrow. We are still at war with Germany, and we are likely to be for some

time; possibly the fourth of March or the fifth, we may have peace.

What are we doing about things, though? Are we interested, really interested? Are we, each one of us, concerned as to world welfare or our own problems? Are we doing what we can for good citizenship; doing our part in the war after the war, which is the most difficult war? You know we were unprepared for war, but our unpreparedness in that respect was just nothing at all compared with our unpreparedness for peace. What are we doing to avert any kind of war? No man has any right of inheritance. The law may take away the estate of the deceased; wipe it out of existence. It has that privilege. No man has any right to his own life. It isn't his. If he is worth anything at all, his life belongs to his country. Do we give enough of our lives to our country? Do we give enough of periods of our lives to our country? Aren't we rather intent on ourselves? Isn't there a good deal of truth in the German idea that we are soft and worshippers of the Golden Calf? Isn't it true?

Many of you worked so wonderfully in the things at home that were essential in order that there be an army at the front. Haven't you forgotten? Haven't you relaxed? Your life belongs to your country. You got it by inheritance. The country can take it. That was proven by the draft. Suppose it should be demanded to-morrow. Give as much as you possibly can to the service of your country and if it should happen to be that in some disturbing time you are called to physically defend what you have and what you stand for, don't be worried about it. There is no better way you can go out, you know, than while serving your colors. Serving *with* the colors is, in the fullest meaning, the privilege of the men in uniform, but everybody can serve the colors. There is no spiritual difference. There is an organized and uniformed distinction in serving *with* the colors, but every man and woman can serve the colors. All of you must—feel that! Feel it anew! Give your American soul a chance! Then, if there shall be trouble (and there may be in spots, but I am not bothered about it), let this inheritance of yours—your life—go where duty calls. Die right, rather than that there shall be a scratch on any one of our constitutional guarantees!

A SURVEY OF VOLTAGE CONDITIONS IN AUTOMOBILE LIGHTING.*

BY H. H. MAGDSICK AND HOWARD KARG.

The motorist who installs a given headlighting equipment developed to produce a certain distribution of light and intensity of illumination is likely to obtain results differing therefrom over a wide range. This condition is due principally to five factors:

1. Variation in individual bulbs (incandescent lamps) as regards candlepower and alignment of filament with reference to the axis;

2. Variation in individual lamp sockets as regards adjustment with reference to the focal point of the reflector and alignment of bulb with reference to the axis;

3. Variation in individual reflectors as regards finish of surface and departure from desired contour;

4. Variation in individual cover glasses as regards proportions of the light directed into the various zones and the percentage of transmission;

5. Variation in lighting systems as regards voltage impressed at the lamp.

A lack of appreciation of the effect on headlighting of unnecessarily wide tolerances in these items has led in many cases to distinctly inferior results; the car manufacturer and the purchaser have not been educated to pay the additional cost of a product conforming to more rigid standards. The metal parts of the headlamp offer relatively less difficulty in accurate manufacture than do the parts involving glass, particularly in the case of the incandescent lamp where many processes have not been adaptable to control through molds, dies or jigs. Even in the case of the incandescent lamps, however, recent investigations appear to point to the possibility of considerably more accurate manufacture being achieved in the future through radical departures from past practice in machinery and processes.

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The greatest factor in the variation of the illumination from a given type of headlighting equipment is the range of voltage impressed at the lamps. The results of an investigation of the magnitude of this variable and an analysis of some of the contributing elements are here briefly reviewed.

Measurements were made of the voltage at each of the lamp positions on a total of 55 cars selected so as to be representative as to numbers in use, make of lighting system, and make of battery. The measurements were repeated in 5-mile-per-hour steps at car speeds in high gear from 0 to 35 miles per hour, both with full lamp load (main head, instrument and rear lamps) and light load (auxiliary head, instrument and rear lamps). The range of voltages found for the three classes of lighting systems in commercial use to-day are indicated in Table I.

TABLE I.—TEST OF AUTOMOBILE LAMP VOLTAGE.

Number of cars tested.. 55
Models of cars tested..1914–1920
Number of different makes of cars.................................... 20
Number of different makes of lighting systems.......................... 10
Number of different makes of batteries................................ 6
Lamps used—Main head, 21 cp.; auxiliary head, 4 cp.; instrument and rear, 2 cp.
Range of car speed (in high gear)....................0–35 miles per hour
Range of voltages:

	Lighting System		
	3-Cell lead battery-generator	6-Cell lead battery-generator	Magneto
At headlamps	4.6–7.9	11.3–17.2	0–10.1
At auxiliary head, instrument, and rear lamps	5.1–8.6	10.3–17.4	

The 3-cell lead battery-generator system is the one most commonly employed and is rapidly superseding all others. The average voltage for these systems at the different speeds and with the several lamp loadings is shown in Fig. 1. The form of the curves for the 6-cell lead battery-generator system is approximately the same, with the value of the ordinates slightly more than twice as great. The data for the magneto lighting system are given in Fig. 2.

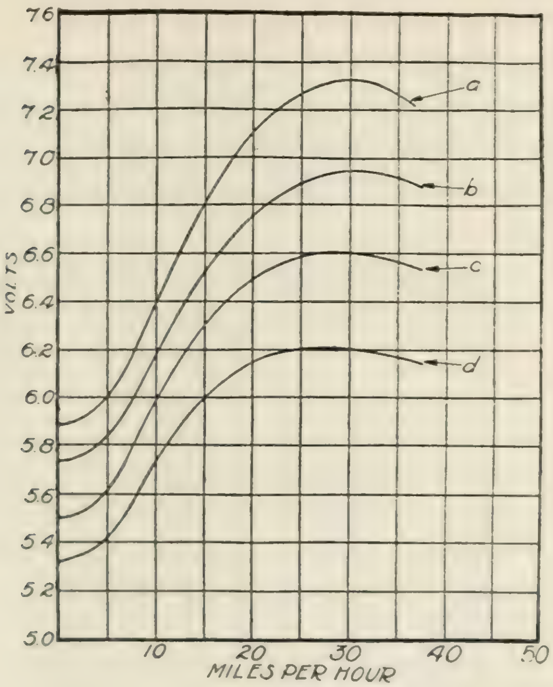


Fig. 1.—Variation of lamp voltage with car speed. Average curves for 6-8 volt battery generator systems.

a, b—Auxiliary headlamps.
c, d—Main headlamps.
a —Light lamp load (auxiliary head, instrument, and rear lamps).
b —Light lamp load plus spot light.
c —Full lamp load (main head, instrument and rear lamps).
d —Full lamp load plus spot light.

Some of the factors which contribute to the range of voltage indicated in Table I are:

1. Characteristics of the different types of lighting systems;
2. Characteristics of regulating devices;
3. State of charge of battery, its capacity, design and method of manufacture, age, and plate condition;
4. The voltage drop in switches, wiring and sockets;
5. The lamp load.

In Fig. 3 are shown the characteristics of the typical designs of generators used for automobile lighting. The change of candlepower of the lamps with car speed is shown rather than the variation in impressed voltage since it is this effect of the voltage which is of particular interest to the motorist. While from the standpoint of the safety and convenience of the driver

the characteristics giving an increasing voltage and illumination with the highest speeds would doubtless be found desirable, there are two limitations which favor a drooping characteristic. These are: first, the adverse effect on lamp life when the voltage is allowed to rise too high, and second, the over charging of the battery which may result. Characteristics of the general form

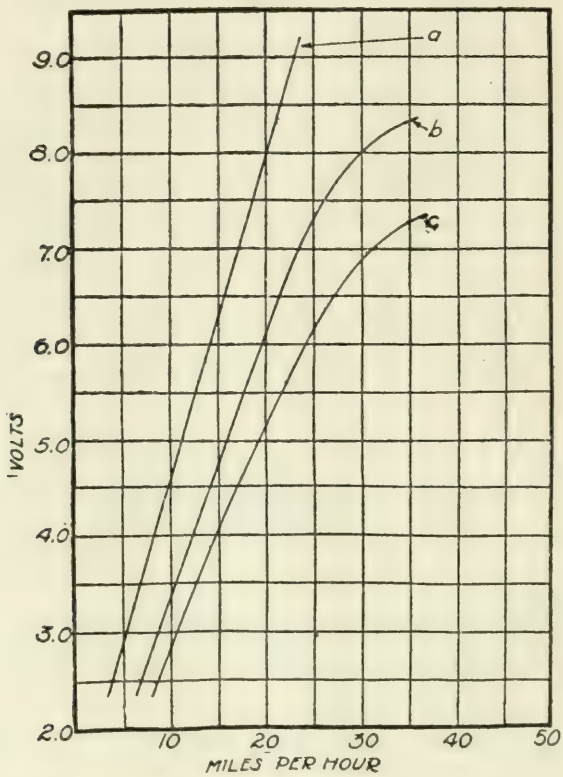


Fig. 2.—Variation of lamp voltage with car speed. Average curves for magneto system.
a—No lamp load.
b—Headlamps of approximately 2.0 amperes.
c—Headlamps of approximately 2.75 amperes.

indicated in curve c have therefore been coming into increasing use and are found on the majority of cars made to-day. The effect of the other variables will therefore be illustrated for cars with this characteristic.

To provide for the various conditions of service requiring greater or less discharge of the battery, means are provided on most cars for adjusting the charging rate by changing the voltage produced by the generator. The effect on the candle-

power of the lamps caused by such adjustment, is indicated in Fig. 4.

When the lamps are in use with the car running, the generator is usually furnishing some energy for charging the battery in addition to that supplied to the lamps. The voltage impressed on the lamps is therefore dependent in part upon the capacity of the battery, its design and method of manufacture, age, and plate condition. The magnitude of the effect of these variables is indicated in Fig. 5 in terms of the resulting candlepower.

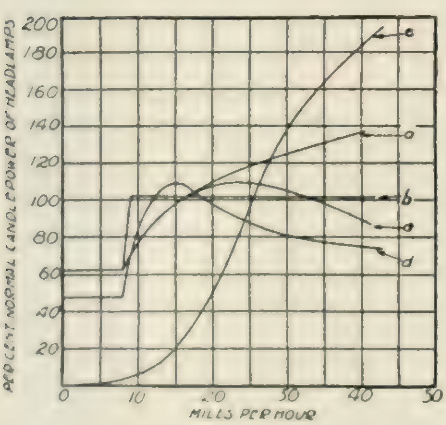


Fig. 3.—Variation of candlepower with car speed on typical lighting systems.

a, b, c, d—Battery-generator systems.
c—Most common type.
e—Magneto system.

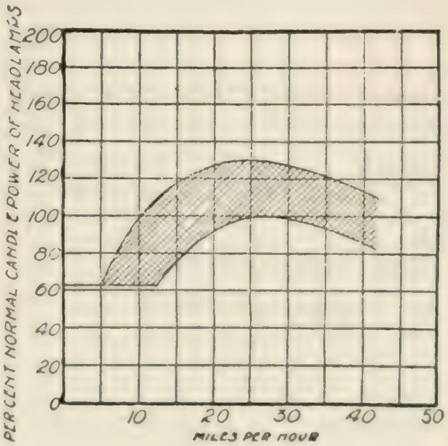


Fig. 4.—Candlepower change resulting from the adjustment of the charging rate over the range provided in representative lighting systems. Curves apply for the lighting system shown in curve C of Fig. 3.

The range of voltage is also dependent upon the state of battery charge. Most of the batteries in service operate over a range of charge within which the charging voltage is fairly constant. In the remaining cases, this variable may be one of the chief factors in determining the light output, but the extremes produced by it alone will be no greater than those indicated in Fig. 5.

To obtain information on the voltage drop in switches, wiring, and sockets, measurements were made on 38 of the cars tested, with the results which are summarized in Table II. The variation is seen to be excessive; in fact, in some cases more than 20 per cent. of the voltage is thus lost. The cases of excessive drop appear to be due to corrosion of contacts and improper design of contact-making and current-carrying parts.

TABLE II.—VOLTAGE DROP IN SWITCHES, WIRING, AND SOCKETS. Number of cars tested—38.

	Total resistance drop			
	Average		Range	
	Light lp. load	Full lp. load	Light lp. load	Full lp. load
6-8 Volt Systems:				
Battery to headlight lamp	——	0.57	——	0.21–1.43
Battery to aux. headlight lamp	0.25	——	0.18–0.81	——
Battery to instrument lamp	0.26	0.42	0.05–0.88	0.05–1.05
Battery to rear lamp	0.29	0.43	0.05–0.83	0.10–1.10
Battery to spot lamp	0.84	——	0.20–1.70	——
12-16 Volt Systems (6 cars):				
Battery to headlight lamp	——	0.31	——	0.10–0.43
Battery to instrument lamp	0.14	0.14	0.01–0.41	0.04–0.49
Battery to rear lamp	0.55	0.48	0.13–1.80	0.09–1.30

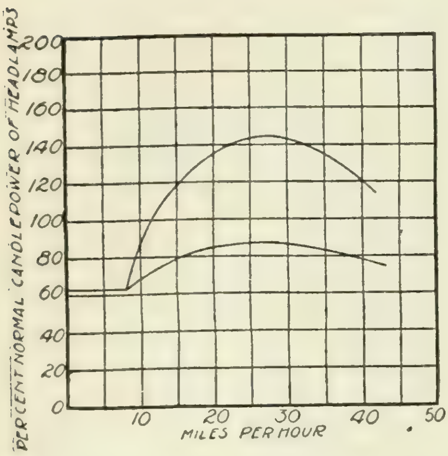


Fig. 5.—Approximate variation of candlepower with make, size, age, or plate condition of battery.

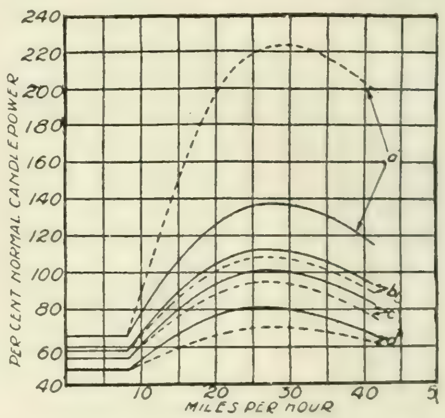


Fig. 6.—Effect of lamp load on candlepower. 240 candlepower may be taken as the representative maximum.

a—Light lamp load (auxiliary head, instrument, and rear lamps).
b—Light lamp load plus spot light.
c—Full lamp load (main head, instrument and rear lamps).
d—Full lamp load plus spot light.

With all of the lighting systems there is a drop in voltage with an increase in wattage of lamps lighted. As the lamp load on the generator is increased the charging current to the battery is lowered. The difference in voltage at the lamps for the several loads commonly employed is influenced also by the resistance of the wire and contacts. The difference is relatively small in the case of a few cars having large generators and batteries; with most cars these are of such small capacity and the generators have such poor regulation that marked changes in the light output occur as indicated in the curves of Fig. 6.

The voltage for which the incandescent lamps are designed, corresponding to the normal candlepower of the above curves. is, of course, determined by weighting the voltages for the different speeds and lamp loads with reference to the relative time these conditions prevail in driving. Some of the data obtained in connection with these weighting factors are presented briefly. Table III summarizes the lamp load as observed for a large number of cars under the range of conditions found on city and suburban streets.

These data were supplemented with information as to the lamps lighted by 96 representative drivers under several conditions, including country roads and highways, with the results shown in Table IV.

TABLE III.—LAMP LOAD EMPLOYED IN CITY AND SUBURBAN DRIVING.

Number of locations at which cars were observed....................12
Total number of cars observed..3,103
Lamps observed in use:

Lamp load	Percentage of cars: Average	Percentage of cars: Range of averages for 12 locations
Light	48.0	28.2–68.0
Light plus spot	21.7	14.2–34.6
Full	26.8	16.7–35.8
Full plus spot	3.5	0.4– 8.4

TABLE IV.—LAMP LOAD REPORTED BY 96 DRIVERS.

	Percentage of cars			
	Light load	Light and spot	full load	Full and spot
Driving in city—well lighted streets	64	16	20	0
Driving in city—poorly lighted streets	19	22	48	11
Driving in country	3	12	67	18
Standing on the street	100	0	0	0

About two-thirds of all cars in this country are owned by the urban population and one-third by the rural. When the relative amounts of city and country driving at night are considered for each of these groups, it appears that lamp loads are used relatively about as follows:

Lamp load	Relative time used for all cars
Light	23 per cent.
Light plus spot	15 per cent.
Full	50 per cent.
Full plus spot	12 per cent.

The relative amount of driving at the several speeds is indicated by the data found to be characteristic for a total of 19 representative drivers, men and women, operating cars of all sizes under different conditions of road surface, illumination, and traffic, both urban and rural. The summary for these drivers is given in Table V. It is of interest to note the difference in driving speeds introduced by traffic conditions on some of these drives, as is illustrated in Fig. 7.

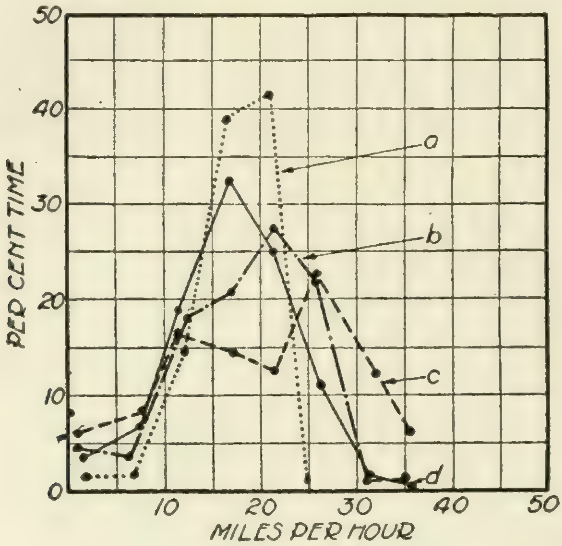


Fig. 7.—Representative driving speeds.

a—Light traffic.
b—Moderate traffic.
c—Heavy traffic.
d—Average for 19 drivers—city and country.

TABLE V.—DRIVING SPEEDS.

Speed range	Average speed in range	Per cent driving time Average	Per cent driving time Range for 19 drivers
0–5	1.3	3.6	0.6–11.1
5–10	7.1	6.8	0.8–12.7
10–15	12.0	19.0	9.6–28.4
15–20	16.8	32.4	14.6–59.0
20–25	21.5	25.0	4.5–44.9
25–30	26.0	11.0	0.5–31.8
30–35	31.0	1.8	0.8–12.5
35–40	35.4	0.4	1.2– 6.3

From the voltage measurements on the cars and the knowledge of typical operating conditions, it becomes possible to gain an idea of the extremes of light output which are likely to be suffered by any considerable number of motorists. Fig. 8

illustrates in Curve A the candlepower of the headlamps for one of the cars tested when driven by a moderately fast driver under conditions typical for suburban or good country roads; in Curve B, the light output from the headlamps for a different model of the same make of car equipped with another make of battery when driven somewhat more slowly over rough country

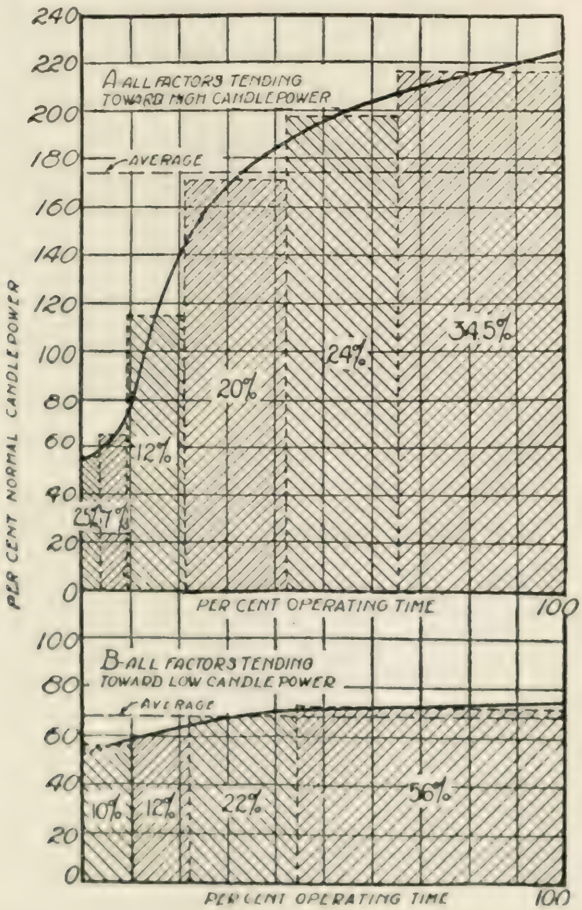


Fig. 8.—Variation of candlepower of headlamps with different battery-generator equipments and operating conditions.
The height of the several rectangles represents the average candlepower for the percentage of the time indicated thereon.
A—Full lamp load (main head, instrument, and rear lamps) per cent. normal candlepower (av.)—175.
B—Full lamp load plus spot light per cent. normal candlepower (av.)—69.

roads where the driver wishes to augment the illumination with a spotlight. In Fig. 9, the light output from the instrument lamps is similarly shown for two of the cars tested of different makes and with different lighting systems and batteries. The one car, Curve A, is driven with light lamp loads at speeds characteristic of the conservative driver on city streets; the other car, Curve

B, with full headlights and spotlights at moderate speed, as is characteristic for rough country roads.

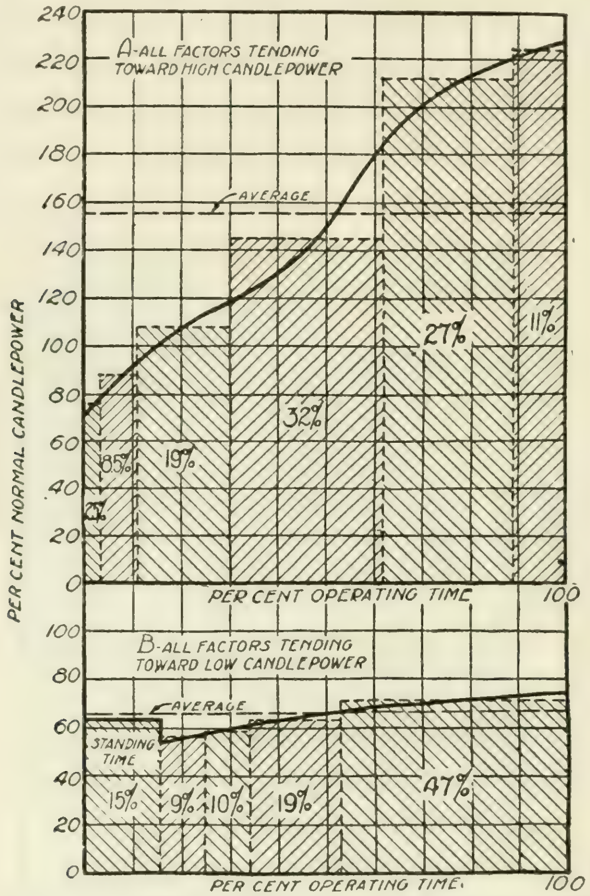


Fig. 9.—Variation of candlepower of instrument lamp with different battery-generator equipments and operating conditions.
The height of the several rectangles represents the average candlepower for the percentage of the time indicated thereon.
A—Light lamp load (auxiliary head, instrument and rear lamp) per cent. normal candlepower (av.)—157.
B—Full lamp load plus spot light (main head, instrument, rear and spot lamps) per cent. normal candlepower (av.)—65.

It is apparent that there is a need for greater standardization and better selection of generator and battery capacities for automobile lighting, further standardization of generator characteristics, improved design of switches and sockets, and more rigid standards as to material and assembly of all parts. Together with these, it is desirable that there be developed a simple and inexpensive regulator to reduce the remaining voltage variation. The importance of improving the existing conditions is emphasized by the fact that the safety and convenience of a very large proportion of the population is affected thereby; in fact, in this country there is now a greater number of electrically lighted cars than homes.

THE OPTICAL PRINCIPLES OF ILLUMINATING ENGINEERING.*

BY P. G. NUTTING.

I. INTRODUCTION.

Your Committee on Papers has requested me to contribute an outline of the optical principles underlying illuminating engineering in a series on "The Knowns and Unknowns of Illuminating Engineering Principles." Having given but little attention to the engineering aspect of this subject for several years past, I ask your consideration of this fact and trust you will not hesitate to comment freely upon such statements as may seem to require it.

One of our chief reasons for organizing the Optical Society five years ago was the feeling that we could make better progress as a smaller separate organization and actually be of greater service to the illuminating engineering profession than if we remained a part of a large organization of many diverse interests. This request from you for a summary of established principles from us is in itself evidence that you are alive to our responsibilities to you. We hope soon to have a return engagement in which you shall outline your further needs to us.

In approaching the subject in hand, perhaps the best general survey is a consideration of the general principles involved. The chief objective of illuminating engineering is to provide (1) efficient lighting, (2) of tasteful design, (3) at a reasonable expense. Good lighting is that which produces good seeing conditions. Ideal lighting would approach daylight in intensity, distribution, direction and color but since such lighting can not be duplicated at a reasonable expense and for many purposes is not really necessary, the illuminating engineer is chiefly concerned with the best compromise between seeing conditions and expense.

Optical principles are involved all along the line; chiefly with seeing conditions at reduced intensities as affected by glare, contrast, time, color and other factors and the best means of produc-

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

ing them and also, to a limited extent, with artistic design in illuminants. The fundamental principles and data involved are now largely available and form the subject of this paper. Interrelations between them may be thus summarized:

1. The number, character and intensities of the light sources determine, by well known optical principles, the illumination.

2. The nature and intensity of the illumination, together with the reflecting and transmitting power of the objects illuminated, determine the brightness and contrast in the objects viewed.

3. Brightness and contrast in the field of view determine luminous flux density at the retina.

4. The character, intensity and distribution of luminous flux density at the retina, with the receptive processes of the retina, determine the nature of the sensation produced.

The illuminating engineer, in providing for comfortable vision of sufficient acuity for the purpose intended, must be familiar with each of the five steps from light source to sensation, together with the optical and psychophysical principles governing the four intermediate transformations just enumerated. It is a vast field of which our knowledge is of the crudest, hence it is not surprising that so many lighting abominations exist or that so few illuminating engineers can handle the more difficult problems in illumination.

Changes 1, 2 and 3 listed above involve chiefly the elementary optical laws of emission, reflection and refraction of light familiar to everyone. Considerable research remains to be done in the field of scattered and absorbed light and certain members of the Optical Society are contributing regularly in this field. The reports of our Standards Committees and probably some regular papers as well will be available to your Society shortly Inventors will doubtless evolve new and improved light sources and diffusing shades and screens.

The very important psychophysical laws governing the reactions of the retina to light (4), are, on the contrary, highly complex and apparently not very well understood by illuminating engineers. Simple illuminating systems are still designed largely by rule of thumb, complex special systems by pure guesswork.

II. CONDITIONS FOR BEST SEEING.

Intensity.—The human eye operates at its best, *i. e.*, perceives slight differences in brightness and color most readily, where the brightness of the object viewed ranges between 1 millilambert (0.002 candle per sq. in.) and 1 lambert (2 c/in.^{2}). Between these limits the seeing is of nearly constant quality but it falls off rapidly at brightnesses exceeding 1 lambert and rather slowly at brightness below 1 ml. down to the lower limit of vision. It may be noted that the four levels of brightness in which interest chiefly centers are roughly: exterior daylight 1 lambert, interior daylight 10 ml., interiors artificially lighted 0.1 ml. and exteriors at night (under full moonlight or moderate artificial lighting) 0.001 ml. The eye ceases to function (everything appearing dazzling) and further adaptation ceases at brightnesses above about 50 l. The lower limit of vision (absolute threshold) is about 0.0000007 ml. The eyes of different individuals, contrary to the general impression, are sensibly alike in absolute sensibility.

Contrast.—The eye operates best when contrasts in the field viewed are not less than about 2 per cent. (98: 100) nor over 1/10 (10: 100). While contrasts depend largely upon the reflecting powers of objects viewed, they also depend largely upon the diffuseness of the illumination since this determines the depth of the shadows. With too diffuse illumination, shadows are lacking, all specular surfaces glitter and the general effect is very unpleasant as is well known. On the other hand, unidirectional lighting gives densely black shadows and harsh effects generally. On a clear day in the open, the light received upon a horizontal plane comes about one-third from the sky and two-thirds directly from the sun.[1] The best ratio of diffuse to total light appears to lie between 30 and 60 per cent. If the light is not a simple mixture of highly diffused with that nearly parallel but is highly diffused within a limited angle (*e. g.*, skylight through a window), seeing conditions are best when diffusion extends over an angle between 0.1 and 1.0 steradian.

Color.—The eye functions best when the objects viewed are illuminated with white or nearly white light but does not fall off

[1] Data by Kimball, U. S. Weather Bureau.

greatly with considerable departures from white approaching spectral hues, provided the brightness remains constant. For work requiring close color discrimination, particularly on nearly white objects, white illumination is essential.

However, illuminating engineers are largely concerned with problems in which the conditions for best seeing cannot be met on account of expense or other conflicting interests. Hence data are required on vision at lower intensities than the ideal, vision with extreme contrasts and even glare in the field and the like.

III. BRIGHTNESS AND RETINAL FLUX DENSITY.

The brightness of the object viewed together with the diameter of the eye pupil, determine the flux density at the retina. Since the brightness may readily be measured (with a brightness photometer) and retinal flux and flux gradients are the fundamental factors in determining the visual response to illuminated objects, it is important to know the retinal flux densities corresponding to each mean brightness of field viewed. From the data of Blanchard[2] and Reeves,[3] on the average pupillary diameter corresponding to each brightness of field viewed, this fundamental data may readily be calculated. Those for the ordinary case of both eyes open are given below. For moderate and bright average fields (2 mm.

RETINAL FLUX DENSITIES AND FIELD BRIGHTNESS.

Field Ml. F	Diameter of pupil		Area effective S	Lumens per mm² E on retina	Lumens per mm²/ml. E/F
	Observed	Effective			
0.00001	7.30	8.17	52.2	7.0×10^{-12}	7.0×10^{-7}
0.001	6.97	7.80	47.8	6.4×10^{-10}	6.4 "
0.01	6.65	7.44	43.4	5.8×10^{-9}	5.8 "
0.1	6.00	6.72	35.4	4.7×10^{-8}	4.7 "
1.0	5.06	5.66	25.1	3.3×10^{-7}	3.3 "
10.	3.86	4.32	14.6	1.9×10^{-6}	1.9 "
100.	2.72	3.04	7.25	9.7×10^{-6}	0.97 "
1,000.	2.08	2.32	4.23	5.6×10^{-5}	0.56 "
2,000.	2.00	2.24	3.94	1.1×10^{-4}	0.55 "

(In the final column of this table are given the lumens per sq. mm. at the retina per ml. of field brightness. The calculations in the 5th column are based on the equation $L = (1/\pi) \times 10^{-5}\ FSn^2/v^2$, in which L is in lumens per sq. mm., F is field brightness in ml., S is the area of the effective pupil, n the mean refractive index of the eye media (taken as 1.34), and v is the equivalent back focal length of the eye (taken as 20.7 mm.). The reduction factor of 1.14/1.02 was used to reduce from the observed apparent diameter of pupil to the actual entrance pupil of the system.)

[2] Julian Blanchard, *Phys. Rev.* 11, 98, Feb., 1918.

[3] Prentice Reeves, *Astroph. Jour.*, April, 1919.

pupil) the ratio is 0.55×10^{-7} lumens per sq. mm. at the retina per millilambert of field brightness. For the lower brightnesses down to the threshold of vision that ratio is about twelve times as great.

IV. THE LOWER LIMIT OF VISION.

Absolute Threshold.—The lowest perceptible brightness depends upon the brightness to which the eye has previously been exposed and the time that has elapsed since that exposure. After full adaptation to darkness lasting an hour or more, the minimum reached is of the order of 0.0000007 ml. At or near this brightness level, no contrasts however great are perceptible. This brightness is roughly one ten billionth of the upper limit (50 lamberts) of contrast perception. The absolute threshold given is for white light but blue and green give nearly the same value. The threshold for red light is about 100 times as great and for yellow 10 times.

Size of Object.—If the object whose visibility is to be tested is of small angular dimensions, it must be much brighter to be just visible. Some data by Reeves (previous reference) are given in the following table. The threshold for a 1 mm. star at a distance of 3 meters is ten thousand times as bright as for a large test

ABSOLUTE THRESHOLD AND ANGULAR SIZE OF TEST OBJECT.

Test object	Observed threshold	Relative total energy
1 mm. at 300 cm.	0.0072 ml.	17
1 " 150 "	0.0026	25
1 " 35 "	0.00024	42
2 " 35 "	0.000028	25
5 " 35 "	0.0000066	37
1 cm. at 35 cm.	0.0000024	25
2 " 35 "	0.0000010	37
3 " 35 "	0.00000045	54
6 " 35 "	0.00000026	01
12 " 35 "	0.00000017	208

field. The product of solid angle subtended by the test object with the threshold brightness, is proportional to the total flux received at the retina given in the final column. This is approximately the same for all the smaller sizes of test object.

Time of Exposure.—When the fully dark adapted retina is exposed for but a short time (a fraction of a second) to light

from a test object, the threshold is higher than for longer exposures. Apparently it is retinal energy rather than retinal flux density which determines visual sensation in this case. Blondel and Rey[4] some years ago observed this effect. Recent data by Reeves (*loc. cit.*) obtained with visual sensitometer and calibrated focal plane shutter are given below. The test spot was 30 mm. square and at a distance of 35 cm.

ABSOLUTE THRESHOLD AND TIME OF EXPOSURE.

Exposure Time (sec.)	Threshold (ml.)	Threshold x Time (ml. sec.)
0.002	0.00036	7.2×10^{-7}
.006	.000097	5.8
.011	45	5.0
.020	24	4.8
.034	12	4.2
0.16	0.0000071	$11. \times 10^{-7}$
.25	51	13
.50	34	18
1.0	26	26
2.0	18	36

These data show the times required to pick up faintly illuminated objects in the dark or conversely the brightness of objects that can just be seen in a given time.

Contrast Threshold.—In such practical cases as that of faintly illuminated signboards at night, the conditions are that a fixed contrast must be perceived in a minimum time with a minimum mean illumination. Data in the table below are obtained with a test spot of the sizes indicated at a fixed distance of 25 cm. The contrast was fixed at 2 : 3. The mean brightnesses at which the contrasting test object could just be perceived in the times specified are given.

CONTRAST THRESHOLD.

Contrast 0.67, Distance 25 cm.

Time	30	25	15	7	3	2 mm. sq.
0	0.00380	0.0080	0.0130	0.0200	0.032	0.049 ml.
2 seconds	.00095	.0023	.0050	.0121	.017	0.35
10 "	.00057	.0012	.0032	.0077	.013	.026
60 "	.00030	.0006	.0020	.0054	.011	.020

Data are not yet available on the depression of threshold sensibility by small bright objects within the field of view and a number of other classes of factors of practical interest.

[4] TRANS. I. E. S., Vol. 7—No. 8, page 6251912.

V. THE UPPER LIMIT OF VISION. GLARE.

The eye is unable to adapt its sensibility to the mean brightness of the field viewed beyond about 50 lamberts (100 candles per square inch). In direct sunlight the brightness of a sheet of white paper is about 10 lamberts, of snow 20 to 30. Snow blindness is caused by the long continued viewing of objects at that brightness level. The value 50 lamberts for the upper limit of vision is obtained by a slight extrapolation of the glare curve to where it cuts the axis of field brightness; that is, it is the brightness at which the sensitizing field itself becomes glaring.

To an eye completely adapted to darkness, the maximum brightness of an object that can just be viewed with comfort if brought suddenly into view is but 20 millilamberts (only about that of objects in a well lighted room at night), the eye being in a highly sensitive condition. Data on the entire range of brightnesses, taken by three observers in good agreement are available.[5]

GLARING BRIGHTNESS OF VARIOUS ADAPTATIONS.

Adapted field brightness	Glaring brightness	Relative brightness
0.000001 ml.	20 ml.	20,000,000.
0.001 "	186 "	186,000.
0.1 "	810 "	8,100.
0.01 lamberts	3.5 lamberts	3,500.
1.0 "	14.5 "	14.5
52 "	52 "	1.0

If log glare be plotted against log field, the relation is found to be linear and fairly well represented by the equation $G = 1700 F^{1/3}$. Hence the just glaring brightness G corresponding to any mean field brightness F may be found by taking seventeen hundred times the cube root of the latter, in whatever units these brightnesses are expressed.

V. NORMAL VISION.

At intensities intermediate between the threshold of vision and the glare limit the average brightness of field viewed, through automatic adjustments within the eye itself, determines (1) the absolute sensibility of the retina and hence the intensity of the brightness sensation, (2) the minimum contrasts perceptible, (3) the maximum (glaring) brightness just tolerable and (4) the pupillary diameter and with it flux density at the retina. These

[5] P. G. Nutting TRANS. 1916 Convention, I. E. S., Vol. 9 – No. 9, page 93[illegible].

data, given in the following table are fundamental in illuminating engineering.

SENSIBILITY AND BRIGHTNESS.

Average brightness of field viewed	Relative sensibility of retina	Contrast sensibility relative to maximum	Minimum glaring brightness of field	Diameter of pupil
0.000001 ml.	0.77	0.017	20.1 ml.	7.4 mm.
0.00001	0.17	0.026	40.7	7.3
0.0001	0.038	0.043	89.	7.2
0.001	0.0077	0.078	186.	7.0
0.01	0.0018	0.22	400.	6.7
0.1	0.00041	0.46	810.	6.0
1.0	0.000087	0.83	1,660.	5.0
10.0	0.000020	0.98	3,470.	3.8
100.	0.0000037	1.00	7,250.	2.7
1,000.	0.00000033	0.72	14,450.	2.1
10,000.	(0.000000003)	0.36	30,900.	2.0

Brightness values are in millilamberts. General sensibility is relative to that at the absolute threshold (about 0.00000070 ml.) taken as unity. The minimum glaring brightness is that just uncomfortably bright to an eye adapted to the brightness of the first column. The diameter of pupil is that for the case of both eyes open. This diameter determines not only retinal flux density but the ultimate limit of resolving power. Contrast sensibility is relative to that at its maximum at ordinary intensities. All sensibilities are referred to normal pupil and normal adaptation, zero for intensity sensibility and glare and about one minute for contrast.

These data apply for equal luminous brightnesses, to all wave lengths. For different individuals having normal vision, the variation is probably not over 5 per cent. from the mean. Brightness sensibility is proportional to the inverse two-thirds power of the brightness of the field viewed, $BxF^{2/3} =$ constant. The minimum brightness producing a sensation of glare is $1700 \times$ the cube root of the field brightness, $G = 1700\ F^{1/3}$. The increment in brightness represented by the contrast sensibility fraction is equal to the unadapted threshold limen. Flux density at the retina in lumens per $cm^2 = 0.134 \times 10^{-5} \times$ area of pupil in $mm^2 \times$ brightness of field viewed in millilamberts.

The intensity of the sensation of brightness cannot of course be directly measured. But since sensibility, which can be measured and which is quite accurately expressible as proportional to the $-2/3$ power of the field brightness, is the first derivative of the sensation, the latter may be obtained by simple integration. This procedure is quite analogous to the simple case of a physical instrument such as an ammeter for which the sensibility is the differential of the scale reading with respect to the stimulus (current). By integration we obtain for the sensation S as a function of the field brightness F,

$$S = 1/3\, F_o^{2/3} (F^{1/3} - F_o^{1/3})$$

the constant of integration being so chosen that the sensation is zero and the sensibility unity at the threshold of vision ($F = F_o$). This remarkable law states that except near the threshold, *i. e.*, for all cases of ordinary vision, *the sensation is proportional to the cube root of the energy flux density producing it.* It was noted above that the glare limit is also proportional to the cube root of the field brightness to which the eye has been adapted, hence the glare limit is of the same dimensions as the luminous sensation as might be expected. Taking the constants into account, the glare limit is 13 million times the sensation at any field brightness.

VII. CONCLUSION.

The above covers some of the more recent developments in applied optics of importance in illuminating engineering. A great many other advances have been made in this and other branches of the subject each of minor importance in itself and too widely scattered in subject matter to permit of brief review here. The list of Standards Committees for 1920 of the Optical Society given below shows the field covered by our research and standardization work. Our informal reports of these Committees at meetings are in reality symposia and serve to bring out much important new information and data. The best of this is gathered in the printed report which serves as the basis for the work of the succeeding committee the following year. These reports cover not only nomenclature, units, standards and standard data but general theory, transformation data and descriptions of approved instruments, methods and materials.

By title, these standards committees are:

1. Colorimetry.
2. Lenses.
3. Optical glass.
4. Photographic materials.
5. Photometry.
6. Polarimetry.
7. Projection apparatus.
8. Pyrometry.
9. Reflectometry.
10. Refractometry.
11. Spectacle lenses.
12. Spectrophotometry.
13. Spectroradiometry.
14. Visual sensitometry.
15. Wave lengths.

In each of these fields the recent advances have been very considerable. As an example of the character of the work, the plan of the work of one committee is given in detail below:

"5. *Photometry and Illumination.*—Nomenclature. Fundamental Relations. Photometric Units and Standards. Approved Instruments and Methods for Photometry, Microphotometry, Comparison Photometry, Illuminometry. Contrast Sensibility. Theory of Sensibility.

"Standards and Tolerances in Illumination. Standard Data on Visibility, Contrast Sensibility, Glare and Adaptation. Sources of Illumination. Diffusing Media. Diffusion Photometry. Reflectometric Methods and Standards.

"Progress during 1920. Bibliography."

It is our plan and hope to gradually accumulate a body of very useful and reliable information suitable in five or ten years to serve as the basis for a permanent reference text in each branch of applied optics. By this means we hope to be of the greatest possible service to illuminating engineering and other allied professions.

A NEW FORM OF PORTABLE LIGHT METER.*

BY DAVIS TUCK.

SYNOPSIS.

This paper describes the construction of a small portable light meter capable of making measurements of the same order of accuracy as the larger portable illuminometers.

There is a real need of an illuminometer that will measure candlepower, millilamberts and foot-candles to a reasonable degree of accuracy, which is readily portable, and which can be obtained for a nominal price.

There are several instruments available at present that are more or less portable, but are really too bulky. A really portable instrument should be small enough to put in a brief case or traveling bag along with one's other necessary effects.

It was for this requirement that the "Light Meter" was developed.

CONSTRUCTION.

In all of the portable illuminometers made in the past there has been a large amount of waste space which contributed to bulk and in many instances to weight as well. In the construction of the light meter practically all of this waste space has been eliminated. The principle involved is that of the inverse square law.

DIMENSIONS.

The overall length is 12 in., the maximum diameter is 2⅛ in. and the weight complete with the battery is 1 pound and 9 ounces.

PRINCIPAL PARTS.

Like other portable illuminometers operating on the inverse square law principle, the principal parts are the battery, the standardized lamp, the switch, the rheostat, the ammeter, the modified Lummer-Brodhun cube and the telescope.

BATTERY.

The battery consists of three dry cells each 2¼ in. long and 1¼ in. in diameter, being one of the standard flashlight batteries. One of the larger forms of flashlight batteries has been used so

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

as to obtain a comparatively long burning period of the lamp before the voltage drop is noticeable.

LAMP.

A lamp was selected which takes a small current from the battery (0.1 ampere) and this is burned at a low efficiency. This has the most desired effect of placing only a small drain on the battery and of maintaining the lamp at its standardized operating characteristics over a relatively long period.

In order to compensate for the yellow color of the light caused by operating the lamp under voltage when compared with the color of the light to be measured (usually Mazda C lamps operating at approximately rated voltage) a blue glass screen has been placed over the lamp housing. This of course has the effect of cutting down the illumination from the lamp, but it has been found that the range of the instrument is ample.

RHEOSTAT.

The rheostat is circular in form and is arranged with a sliding contact so that resistance is cut in or out by turning the ammeter about its axis. When all of the resistance is cut in the sliding contact rides on an insulated plate that functions as a switch. In this way the lamp is at all times protected from having too high a voltage suddenly placed across it by an unskilled operator or by absentmindness on the part of the skilled operator.

AMMETER.

The ammeter is of the D'arsonval type and the shunt is made to give practically full scale reading when the lamp is operated at the standardized current. The glass over the face of the ammeter is put on similar to a watch crystal so that the scale on the ammeter can be easily accessible for marking the calibration point. The method of assembly of the rheostat switch and ammeter makes for compactness and lightness and makes wired or soldered connections unnecessary. Fig. 1 shows the assembly of these parts.

The connection between the battery and the rheostat assembly is made by a coiled spring similar in construction to the ordinary

540 [9]

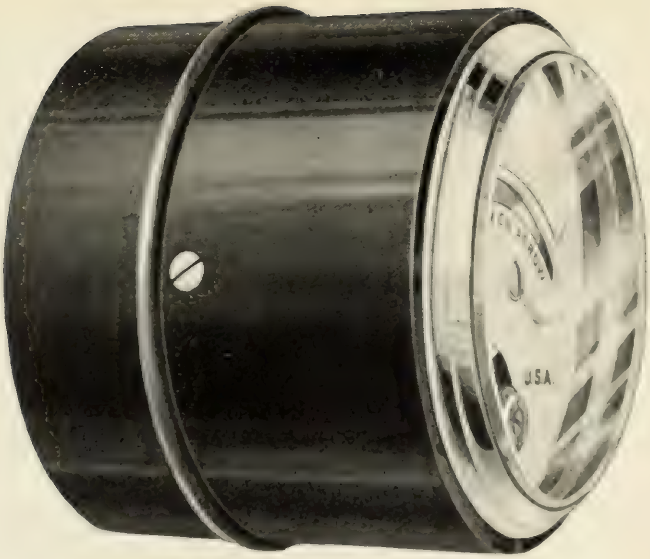


Fig. 1.—Assembly of rheostat, switch and ammeter, full size.

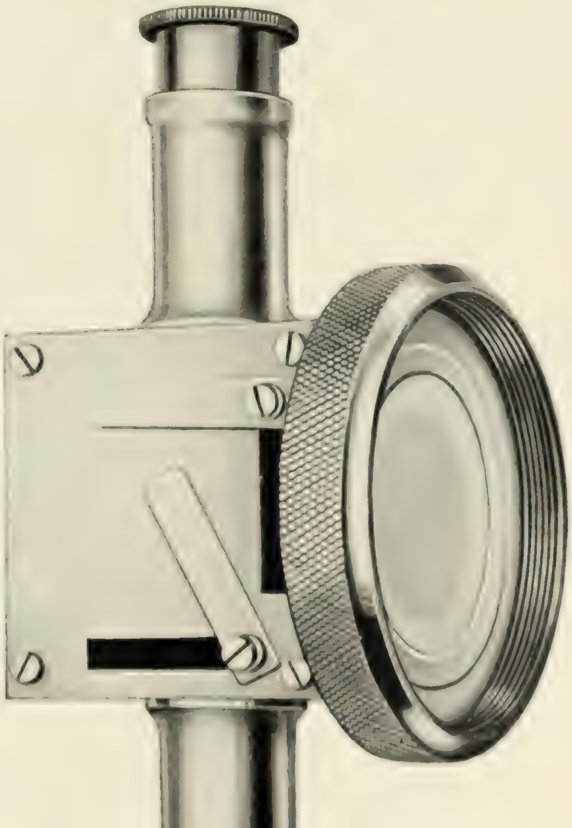


Fig. 2.—The photometric element assembly. Full size.

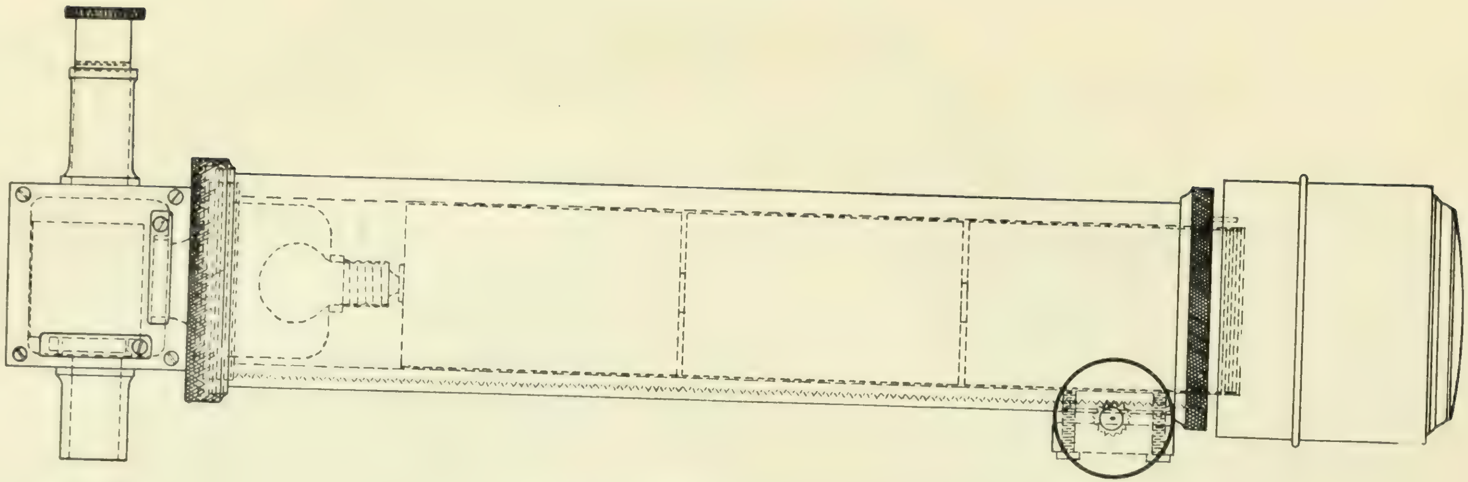


Fig. 3.—Portable light meter. One-half full size.

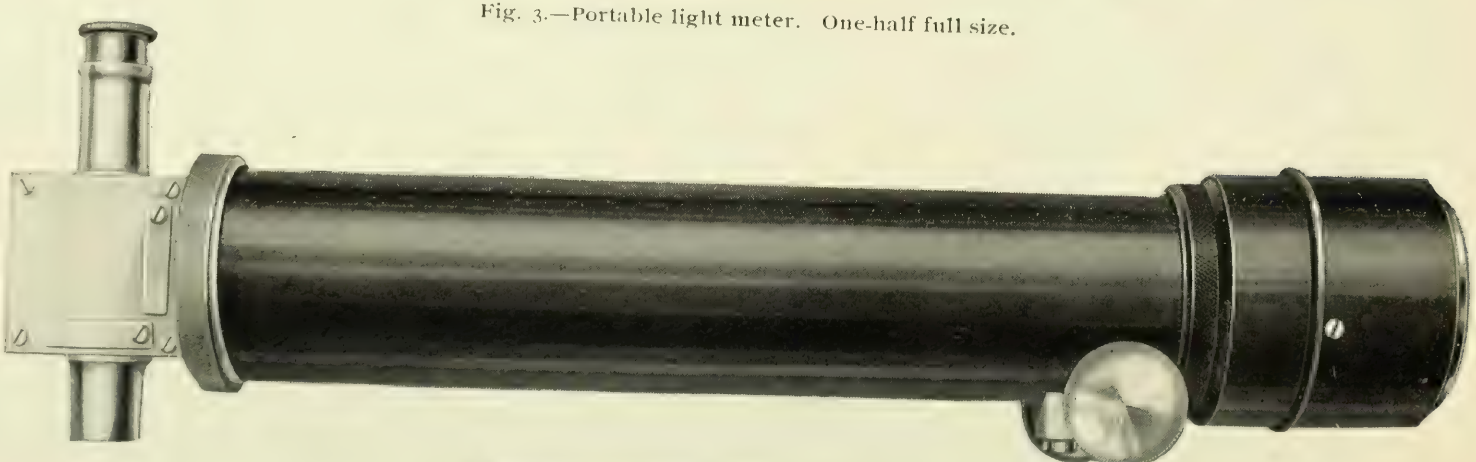


Fig. 4.—Portable light meter. One-half full size.

flashlight. New batteries can be inserted without the use of solder or screwdriver.

MOVING PART.

The tube which carries the battery and rheostat assembly also carries the lamp housing. The lamp is placed in a half sphere with a piece of blue glass ground on one side over the opening. This construction has the advantage of avoiding the inequalities of illumination due to various lamp orientations and places the lamp in a dust tight protected chamber. The ground blue glass plate is a secondary light source and its distance from the piece of milk glass in the light meter head determines the calibration constant of the instrument. Small variations in lamp measurements therefore do not affect the scale calibration.

The sliding tube carrying the rheostat assembly, the battery and the lamp has a wool yarn piston ring at the lamp end and an externally expanding metal piston ring on the rheostat end so that the proper friction is obtained on the sliding tube. A rack and pinion is provided for sliding the tube.

Three scales are provided showing candlepower, millilamberts and foot-candles respectively. The scales are engraved on the sliding tube.

THE PHOTOMETRIC ELEMENT.

The photometric element assembly, shown in Fig. 2, screws on the tube which houses the moving part.

The photometric device is a modified Lumner-Brodhun cube. The telescope has an adjustable focus.

RANGE.

The range of the foot-candle scale is from 0.5 to 15 foot-candles. Provision is made for inserting neutral tint screens either on the test or comparison side of the cube. The screens used have a transmission factor of 10 and 1 per cent. respectively so that the range is increased to .005-1,500 foot-candles.

Provision is also made for inserting a yellow color filter in the sight tube so that an approximate color match can be made with daylight for making measurements under daylight conditions.

PRECISION.

Tests that have been made under both laboratory and field conditions indicate that the average deviation from the mean of a series of measurements compare favorably with the Macbeth and Sharp-Millar photometers, being approxmately 1 per cent.

The gospel of good lighting has been preached for several years and there is a real demand for such an instrument as has been described. It is hoped that the Light Meter will soon be available as a medium priced, readily portable, accurate instrument for light measurements.

DISCUSSION.

WARD HARRISON: A short time ago I had an opportunity to make some readings with this instrument. My impression was that it combined in considerable measure the advantage of several of its predecessors in being of light weight and compact, at the same time more of an instrument of precision than the foot-candle meter. What we are interested in particularly at this time is definite information as to when such an instrument will be on the market. It is presumed that this instrument will be more expensive than the foot-candle meter but its greater accuracy will make it a necessary part of the equipment of many illuminating engineers.

G. H. STICKNEY: From my examination of this instrument, I have been favorably impressed. If, as now appears likely, illumination quantities are to be measured and used more extensively, there certainly should be room for such an instrument as this in addition to those already available.

While the foot-candle meter will undoubtedly be used more widely, especially by laymen, this instrument has advantages for those who desire accuracy or who wish to make brightness measurements. It has an advantage in regard to portability as compared with the other types of accurate instruments. It should, therefore, be encouraged as tending to popularize illumination measurements and so advance the art.

F. C. CALDWELL: This light meter with its relatively high accuracy, is timely in connection with the enforcement of lighting

codes. The foot-candle meter is very useful in laying out and maintaining intensities, but when it comes to a legal point of view, the percentage error that has to be allowed for with that instrument seems pretty large to the man who has only been used to measurement of space and time.

LOUIS BELL: I want to speak a word of appreciation for our friend, who has turned out a really portable photometer of the precision variety, because I feel just as Prof. Caldwell and some of the others, that in industrial code work we have got to have something which is a fairly precise instrument, within a pretty close limit, and at the same time a simple and portable one.

Everybody appreciates the foot-candle meter. The foot-candle meter, is and will continue to be, a mighty good skirmishing instrument, but when you have to face the proposition of calling down the manufacturer in the practice of the code and have to bring the situation into court, I can see very easily where the foot-candle meter is going to receive rather rough treatment at the hands of the attorneys, simply because it reads by steps, and while it is very good, when skillfully handled, you can't always bet that a twelve-hundred-dollar inspector will handle it with the necessary degree of skill.

We have all of us wrestled with the portable photometer and the difficulty has always been to find some such way of putting it over a wide range. Most photometers have fallen down in that particular. In this instrument, no attempt is made for a primary range beyond the ordinary scope of interior lighting, the secondary range being secured by the modification screens.

These are open to some objections. It is hard to calibrate them, and they must be kept clean, and all that sort of thing, but at least we have here a working range that corresponds with most of the usual intensities, which will enable us to use the instrument on serious code work where values have to be tested. It is a very considerable step ahead.

CHAS. FRANCK: I think I should be allowed to answer Mr. Harrison as to the question of when such an instrument might be available. Mr. Tuck has been very insistent for the last eight months or a year to bring this little device out on the market, and

finally, as his co-partner we agreed that we would like to bring this instrument before this body. After the very encouraging reports I heard from Prof. Caldwell, Mr. Hoeveler and Mr. Harrison and the other gentlemen I might say that Mr. Tuck and I will get busy and although we don't want to promise anything definite, I believe in the early part of 1921, we will have this light meter available.

DAVIS TUCK: About all I have to say as to when the instrument will be available, is that I want to pick the manufacturer. I think the appearance of this instrument will have something to do with the court. A scientific-looking instrument will impress one as being scientific. I want it made right. There are very few companies in the country that can do that, and I want to try to get one of those.

KNOWNS AND UNKNOWNS OF LIGHT PRODUCTION.*

BY G. M. J. MACKAY.

From time to time it is well for us to summarize our knowledge and the problems that still confront us somewhat after the fashion of an organization listing its assets and liabilities and preparing a budget for the future. In the field of illuminating engineering this is rather a complex undertaking since every branch of science is involved to a greater or less extent. However, an attempt will be made to give some general idea of what is known regarding the production of light, and to point to some of the problems which yet remain to be solved.

The production of light is still one of the most inefficient transformations of energy, though the actual cost to the consumer is relatively very small in comparison with the utility and convenience of modern lighting systems. If we had a unit to express the value in health, happiness, and productiveness, of the actual service rendered, the cost of product would be low in comparison with almost any other necessity or luxury. For instance, compare the cost of lighting the average home with the cost of telephone communication, or transportation, and consider night with absolutely no artificial illumination as a profitable substitute.

Nevertheless, the hatred of the scientist and engineer for inefficiency, and his interest in unsolved problems—the spirit of Kipling's "Explorer"—will force him to push the frontier of knowledge and accomplishment still further into the unknown.

"There's no sense in going further—it's the edge of cultivation,"
So they said, and I believed it—broke my land and sowed my crop—

Built my barns and strung my fences in the little border station
Tucked away below the foothills where the trails run out and stop.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

Till a voice, as bad as Conscience, rang interminable changes
On one everlasting Whisper day and night repeated—so:
"Something hidden. Go and find it. Go and look behind the Ranges—
"Something lost behind the Ranges. Lost and waiting for you. Go!"

Then, too, the mechanism of radiation is one of the most fundamental problems in physics, and who knows but that when it is solved, the resulting knowledge in other fields may not be of inestimable value.

EFFICIENCY OF ILLUMINANTS.

In order to determine the luminous output of a radiant source, the radiation emitted has to be evaluated according to its ability to produce the sensation of light. The maximum efficiency possible, or the watts per lumen of monochromatic light of greatest visibility, 5560 Angstroms, according to the measurements of Hyde, Forsythe, and Cady,[1] is 0.00150 watts per lumen. The total luminous efficiency of a source may then be obtained by dividing the luminous output expressed in watts by the total energy input.

The following table shows the total efficiencies of some typical illuminants as obtained by H. E. Ives.[2]

	Lumens per watt	Total luminous efficiency
Ideal yellow green	617.	1.00
Solar radiation[3]	86.5	.138
Open yellow flame arc, D. C.	44.7	.072
Quartz mercury arc	42.	.068
Mazda C incandescent	19.6	.032
Moore nitrogen tube	5.21	.0085
Carbon incandescent	2.6	.0042
Incandescent gas lamp	1.2	.0019
Petroleum lamp	.26	.0004
Open flame gas burner	.22	.00036

The best sources of light are therefore extremely poor when compared with the theoretically ideal conversion of energy into monochromatic radiation of greatest utility. The showing is not quite so bad, however, if comparison is made with the most efficient white light theoretically possible. The efficiency of such a source, considering the energy necessary to produce continuous

[1] *Phys. Rev.*, 13, (1919), p. 45.
[2] *Phys. Rev.*, 5, (1915), p. 390.
[3] Ives, TRANS. I. E. S., 11, (1916), p. 888. Kingsbury, *Phys. Rev.*, (1916), p. 161.

or "black body" radiation in the visible portion of the spectrum only, say between the wave lengths 7600 A. U. to 4000 A. U. at a temperature of about 6500° K., would be about 50 per cent. when compared with the ideal monochromatic light.

METHODS OF LIGHT PRODUCTION.

The various means of producing light may be classed as follows:

1. Radiation from solids induced by heat, including
   (*a*) Electrically heated filaments,
   (*b*) Arc electrodes heated by electrical discharge,
   (*c*) Flames of incandescent carbon.
2. Radiation from gases or vapors produced by electrical discharge.
3. Fluorescence and phosphorescence stimulated by radiation or electron impact.
4. Chemi-luminescence, or the emission of light at low temperatures due to chemical reaction.

Radiation from hot solids approximates in general character to that emitted by a "black body," that is, by the inner walls of a completely enclosed space. The limitations to the attainment of high efficiency are the comparatively low melting points, high rate of evaporation, and wasteful radiation in the infra red and ultraviolet, which are characteristic of the materials we have to deal with. True, some substances show a slight selectivity in their radiation, but not enough to warrant any great hope of a large increase in efficiency. Tungsten, for example, at its melting point, 3670° K., has a luminous output of about 51 lumens per watt, but has a rate of evaporation corresponding to 1 milligram per square centimeter of surface per second. It is somewhat selective, having a considerably lower emissivity in the infra red than in the visible portion of the spectrum. If it were simply a "gray body," that is, one radiating at all wave lengths the same fraction of the energy emitted by a "black body" at the same temperature, its efficiency would be the same though its intrinsic brightness would of course be less. Thus at 2000° K., the lumens per watt for a carbon filament which more closely approaches a "black body" in its radiating properties is about 1.9, while for tungsten at the same temperature we have 3.3 lumens per watt.

Weniger and Pfund[1] have found, however, that with increasing temperature the emissivity of tungsten increases for wave lengths longer than 12700A and decreases for the shorter wave lengths, so that the tendency is for the metal to act more like a complete radiator, and consequently with comparatively poorer luminous efficiency, as the temperature is raised.

Unless we learn to control the emissive properties of matter, or find a new material with lower rate of evaporation and higher melting point, increase in the efficiency of incandescent filaments appears to be limited to the possibility of decreasing the rate of loss of material, such as by an envelope of gas with a higher atomic weight than argon, or by a regenerative chemical agency.

That variety of electric arc which depends upon the luminosity of its electrodes, has the advantage over the filament in that a more rugged construction may be used allowing a higher temperature to be reached. In this way, materials may be operated at their boiling point, if, as with the carbon arc in air, it is permissible to replace the electrodes at fairly short intervals. A drawback to this form of heating is the fact that the arc has a negative volt-ampere characteristic which necessitates some means for maintaining the current constant.

Luminous flames appear to have the same radiant qualities as incandescent solids, due to the overpowering of the spectra of the burning gases by the particles of white hot carbon liberated by the combustion. Thus Hyde, Forsythe, and Cady[2] have found that the energy distribution in the spectrum of the acetylene flame in the visible region, 4000 A. U. to 7000 A. U., may be considered equivalent to that of a black body at 2360° K. The use of a colorless bunsen flame, where combustion of the carbon is complete, to heat a mantle of infusible oxides is also somewhat similar in principle. Ives, Kingsbury, and Karrer[3] find the maximum possible total luminous efficiency for the proper mixture of oxides giving selective radiation when heated by the bunsen flame at 2000° K. to be 2.6 per cent. This is over thirteen times that of the present mantle gas light (0.0019), but slightly below the gas filled tungsten lamp (0.032).

[1] *Phys. Rrv.*, **14**, (1919), p. 427.
[2] *Phys. Rev.*. **14**, (1919), p. 379.
[3] *J. Frank. Inst.*, **186**, (1918), pp. 401, 585.

The poor efficiency of flames is due to the great difficulty of localizing the heat of combustion sufficiently well to give a high temperature, and to the high losses due to convection and conduction.

The disparity between the efficiency of the flame and an electric lamp is not so great, however, if we consider the loss of energy involved in the production of electricity from coal.

A more attractive field for speculation, and in the understanding of which, very rapid progress has been made in the last fifteen years, lies in the luminous effects produced in gases and vapors by electrical discharge. If we simply heat a gas or vapor such as argon or mercury to, say 3200° K., as has been done in the gas-filled lamp, no luminosity whatever is visible. If, however, an electric current be passed through the gas, radiation of great brightness may be obtained. Such radiation is not continuous as in the case of an incandescent solid, but is emitted in a number of lines of definite wave length which are characteristic of the substance excited. In the spectrum of each element, also, the lines show more or less definite relationships with one another, and in many cases can be separated into groups in which the position of the individual members may be described by a mathematical formula. Thus Balmer in 1885 showed that the frequency, ν, of the first nine lines of hydrogen could be expressed by the equation

$$\nu = N\,(1/n_1^2 - 1/n_2^2)$$

where N is a constant, n_1 is 2, and n_2 is given the values 3, 4, 5, 6, 7, 8, 9, 10, and 11. With a value for N of 3.29×10^{15} the calculated values for the wave lengths of the lines fall well within the limits of experimental error. Since then, this relationship has been found to hold into the ultra-violet with surprising accuracy, and similar equations have been found to express the arrangement of lines in the spectra of other elements. The wave lengths emitted are thus functions of successive whole numbers, or have a "series" relationship. The spectra may also contain several series of lines such as the principal, subordinate, diffuse, sharp, etc., all described by a similar expression.

Such a relationship, of course, suggested a clue to the nature of the mechanism causing the emission of light. Little progress

was made, however, until 1913, when N. Bohr,[1] of Copenhagen, presented a picture of the structure for the simple atoms of hydrogen, helium, lithium, etc., which correlated the phenomena of radiation with the electrical forces producing them, by using Rutherford's representation of the atom, and a system of mechanics based on the quantum theory which differs considerably from the orthodox Newtonian scheme.

It is interesting to know that this "quantum theory" which has been applied in such diverse fields as the photo-electric effect, X-ray spectra, and specific heats, had its origin in the derivation of the law describing the distribution of the radiant energy of a black body as a function of the temperature by Planck.[2] This relationship is

$$E_\lambda \, d\lambda = 8\pi RT\lambda^{-4} \, d\lambda \, \frac{h\nu/RT}{e^{\frac{h\nu}{RT}} - 1}$$

where ν is the frequency corresponding to wave lengths λ, and h is Planck's constant which has the value 6.56×10^{-27} (ergs sec.).

Since then it has been found that this constant appears as a factor in the description of many other phenomena. For instance, when a beam of light of frequency ν falls on the active surface of a photoelectric cell, electrons, of individual charge e, are emitted at a velocity corresponding to the voltage V defined by the equation

$$Ve = h\nu.$$

Similarly in the production of X rays, the limiting frequency of the radiation given out is shown by the same formula where V is the voltage through which the electrons fall.

The investigation of the specific heats of substances at low temperatures also demands an energy quantity $h\nu$ to describe the phenomena involved.

In fact when we leave that domain of physics which has concerned itself with matter on a scale very large with respect to its ultimate structure, and enter the region of extremely small scale phenomena, we find that the results of our experience with the every day world as described by Newton's laws can not be applied to correlate the mechanics of such systems. The idea of

[1] *Phil. Mag.*, 26, pp. 1, 476, 857.

[2] *Ann. d. Phys.*, 4, (1901), p. 553.

continuity in natural processes has to be replaced by one which involves abrupt changes resulting in losses or gains of energy denoted by the product $h\nu$.

Rutherford conceives the atom to consist of a central nucleus, positively charged, surrounded by negatively charged particles or electrons which revolve in planetary orbits about the nucleus. The latter possesses practically all the mass of the atom though in no case larger than 1/10000 of the diameter of the whole system. If the charge on the hydrogen nucleus be unity, then the charges on the other elements increase step by step with increasing atomic weight, a single positive charge being added to the nucleus for each position in Mendelejef's periodic table. Thus the "atomic numbers" of helium, argon, mercury, and uranium are respectively 2, 18, 80, and 92. This number also represents the number of electrons in each atom.

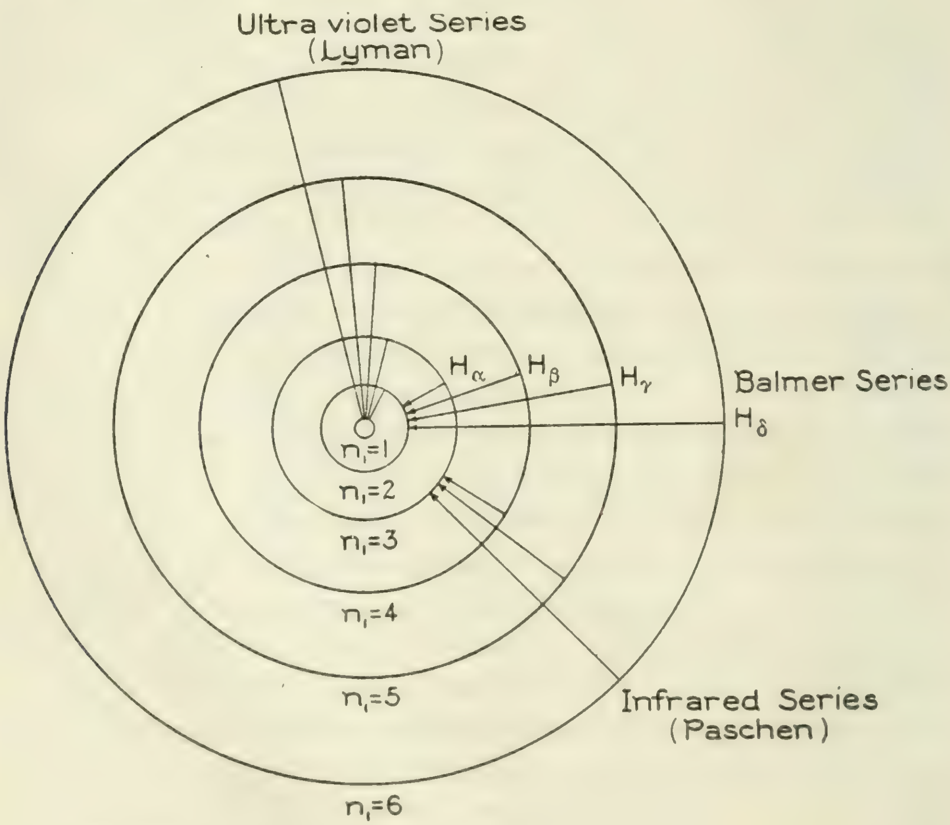
Now the production of visible radiation appears to be the result of a disturbance of the equilibrium between the component parts of the atom—the nucleus and the electrons—light of definite wave lengths being emitted. Bohr calculates in accordance with the classical mechanics the conditions which make possible the orbital motion of the electrons around the nucleus. But, if in this state, energy is dissipated by radiation, the diameter of the orbit should gradually decrease and the frequency increase so that light of continuously changing wave length would be given out, and a definite line spectrum would be impossible. To avoid this difficulty Bohr makes use of the quantum of energy, $h\nu$, and assumes that the emission of energy is discontinuous, and occurs when an electron suddenly jumps from one orbit to another. Exactly one quantum, $h\nu$, is involved in this change, and absolutely monochromatic light of frequency ν is liberated.

The hydrogen atom is pictured as a system consisting of a nucleus with one electron rotating in a planetary orbit and having any desired number of possible orbits further from the center to which the electron may be removed by an expenditure of energy. As it tumbles back to a stable position, a definite spectral line is emitted the frequency of which depends upon the two orbits it falls between. This conception allowed Bohr to calculate the frequencies of the Balmer series, and the value of the constant

N, which agree with the experimental facts. He also calculated the ionizing potential, or the voltage necessary to completely remove the electron from the atom, 13 volts, which is very close to the experimental result. His determination of the heat of dissociation of the molecule into atoms, however, does not check quite so well, but indicates the magnitude approximately. He also prophesied another series of lines in the ultra-violet, unknown at the time of his paper, but afterwards discovered by Lyman.

Since then various modifications and refinements have been proposed, and the problem of the ultimate nature of atomic structure is still in an unsettled state. Langmuir's theory[1] better correlates the vast accumulation of chemical data, but has not yet been developed to describe the phenomena of radiation. Bohr's picture is so decidedly helpful, however, that it probably represents at least part of the truth.

The following diagram given by Sommerfeld[2] gives an idea of the mechanism described by Bohr.



[1] *J. Am. Chem. Soc.*, **41**, (1919), p. 868.
[2] *Atombau und Spektrallinien*, 1919.

The normal un-ionized atom consists of the nucleus and an electron rotating in orbit 1. The lines of the Lyman series in the ultra-violet then occur when the electron returns to this orbit from any of the others. The lines of the Balmer series are emitted when the electron returns to orbit 2, and of the Paschen series in the infra-red by a return to orbit 3. The disturbance produced in each atom may only give rise to a single line at one time, but as each atom may have its electron removed to a different orbit, the resulting radiation from many atoms will give the complete spectrum.

Later experimental work has produced many extremely interesting results which may have a direct bearing on the more economical production of light. Franck and Hertz[1] found that when mercury vapor at low pressure was bombarded by electrons having a velocity corresponding to 4.9 volts, a single spectral line was emitted of wave length 2536 A. U. This was found to be in accord with the quantum relationship $Ve = h\nu$. J. C. McLennan and his students[2] then showed that the same equation held for the production of single line spectra in the vapors of zinc, cadmium, and magnesium when stimulated by low voltage electrons from a hot cathode. Both of these observers, however, declared that the emission of such lines was accompanied by ionization of the vapor. Davis and Goucher,[3] on the other hand, found that when the line 2536 A. U. was produced by 4.9 electron impact no ionization occurred, and further, that an additional line 1849 A. U. appeared when the voltage was increased to 6.7, where again the relationship $Ve = h\nu$ held. Finally ionization occurred without an apparent increase in radiation at 10.4 volts. From the quantum relationship this should correspond to the emission of a line having a frequency of the shortest wave length of the principal series of mercury. Absence of increase in radiation at 10.4 volts was probably due to the low pressure at which the experiments were conducted where recombination of the ions was prevented by the effect of the applied field in removing the charged particles as soon as formed.

[1] *Verh. d. Deutsch. Phys. Ges.*, 16, (1914), p. 457., 17, p. 512.

[2] *Proc. Roy. Soc.*, A91, (1915), p. 485, 92, p. 307, *Phys. Rev.*, 10, (1917), p. 84, *Proc. Phys. Soc.*, 31, (1919), p. 1.

[3] *Phys. Rev.*, 10, (1917), p. 101.

Investigation of other gases and metallic vapors, by Tate, Foote and Mohler, and others[1] have shown in general, similar effects.

It thus appears that when electrons from a hot cathode strike the atoms of a gas or vapor at very low voltages, they may be reflected until the so-called resonance potential is attained when all the energy of impact is absorbed and single line radiation produced without ionization. As the voltage is still further increased to its ionizing value, an electron is completely ejected from the atom, and as these recombine to form the neutral atom again, the complete spectrum is obtained. On the Rutherford and Bohr hypothesis ionization consists in removing an electron to a practically infinite distance from the nucleus. Resonance may be looked upon as the result of a simple removal of an electron from one orbit to another, and its return. The voltages involved in both cases are all comparatively low. Thus helium has the highest ionization potential, 27 volts,[2] or according to Franck and Knipping, 25.4 volts.[3]

Now since all the energy of the electron is converted into monochromatic radiation at the resonance potential, it would appear that in this particular part of the process a perfect conversion of energy into light should be realized if the single line emitted occurs at the point of maximum visibility in the spectrum, 5560 A. U. The voltage range necessary to excite visible light, from 4000 A. U. to 8000 A. U. should be 3 to 1.5, and for the production of a wave length 5560 A. U., 2.2 volts. These values are obtained by substituting the proper quantities in the equation

$$Ve = h\nu$$

$$\text{or V (in volts)} = \frac{12340}{\text{wave length (in Angstroms)}}.$$

The single lines so far obtained are usually quite faint,[4] the current used for stimulation small and the pressure of gas low. When the current is high as in the arcs of several amperes described by Mackay and Ferguson,[5] where the total drop between the electrodes is less than the ionization potential of the

1 *Phil. Mag.*, **36**, (1918), p. 64, **37**, p. 33.

2 *Rentschler Phys. Rev.*, **13**, (1919), p. 297.

3 *Phys. Zeit.*, **20**, (1919), p. 481

4 McLennan, *loc. cit.*, Foote and Meggers, *Phil. Mag.*, **40**, (1920), p. 80.

5 *J. Frank. Inst.*, **181**, (1916), p. 206. and Hebb, *Phys. Rev.*, **12**, (1918), p. 482.

gas, the many lined spectrum is obtained. There is little doubt, however, but that in many cases with low voltage discharge, greater relative intensity may be obtained in the visible region than when the potential is high, with a corresponding gain in luminous efficiency.

The efficiency of such sources is limited to a certain extent by the amount of energy necessary to produce an electron stream to excite the gas, so that the solution of the problem from this point of attack depends upon the production of free electrons at as low a cost as possible.

To illustrate the magnitude of the factors involved it may be interesting to consider an ideal case of a discharge tube using a hot tungsten cathode separately excited and a discharge voltage of 2.2 volts. The electron emission from tungsten per square centimeter of surface, and the emission per watt, vary with the temperature as follows:

Temp. °K	Amperes per sq. cm.	Amperes per watt
2,000	0.004	0.00015
2,400	0.37	0.006
2,800	8.4	0.066
3,200	100.	0.41

Thus with a tungsten cathode operating at 2800° K., or at the temperature of the filament of a mazda C series lamp, there is available 8.4 amperes of electron current per square centimeter of surface at a specific consumption of 15 watts per ampere. Such an electron stream at 2.2 volts should produce in the ideal gas, light equivalent to the ratio of the watts input, 18.5, and the mechanical equivalent of light, 0.0015, or 12,300 lumens. The watts used in the filament, however, for the production of electrons, amount to 126 which also give 2300 lumens. The overall efficiency would then be $\frac{12,300 + 2300}{18.5 + 126}$ or 101 lumens per watt, or a specific consumption of 0.13 watt per candle.

It is ordinarily impossible, however, to obtain such high electron currents from a cathode even at moderately high potentials due to "space charge" or the effect of the mutual repulsion of similarly charged particles upon one another which limits the current. This can be overcome by the presence of oppositely charged

ions, but this requires the production of ionization which again lowers the efficiency of radiation. Therefore in order to obtain the ideal transformation of energy not only is a more efficient electron source desirable, but also some method of reducing "space charge."

The problem of producing fluorescence or phosphorescence in materials by radiation or electron impact, or by chemical action at ordinary temperatures, by a practical method, is still so involved and far from solution that we shall not consider it at present. Progress is now being made so rapidly, however, in atomic exploration, that at any time discoveries may be made which may revolutionize present methods.

DISCUSSION.

E. F. Nichols: Gentlemen, it seems to me a very useful thing to have had such an admirable paper in such compact form as Mr. Mackay has given us of the ways by which we are actually producing illumination and some of the ways by which we may find it possible to produce better illumination in the future.

The physicist plainly sees his duty in this matter. It is written all over the face of things. He is just passing through what amounts to a revolution in his orderly household, a revolution resulting from some very recent and astounding discoveries concerning the structure of matter and the constitution of energy. From this new material and these new ideas, once digested, new applications of physics to the useful arts must multiply. It is preeminently a time therefore for following up new leads and it is especially a time for taking stock of results already attained and tracing out any suggestions however tenuous which spring from our new knowledge.

There are men still living who in college in the sixties and seventies of the last century saw lecture room experiments in physics and chemistry showing a feeble arc light fed at great expense from a battery of Grove cells; saw also a glowing platinum wire heated by current from the same extravagant source, and heard their reputedly 'optimistic but eminently impractical professors' predict that some day we would light our homes and streets by electricity.

Now I think there is quite an equal probability that before long some of the possible sources of light enumerated in Mr. Mackay's admirable paper will turn out to be commercially profitable and there are doubtless yet other sources not mentioned which may develop an unguessed usefulness.

There is this hope ahead of us and it is particularly gratifying to physicists and engineers alike that here is a field where both can work together. We must keep in each other's counsels, take each others advice, face and overcome common difficulties in behalf of all mankind whom as physicists and engineers alike we strive to serve.

MODIFIED VIEWS ON THE THEORY OF LIGHT.*

BY ERNEST FOX NICHOLS.[1]

By his profession the illuminating engineer is numerously related to several sciences and a number of the arts. In particular, it is to the discoveries in physics and chemistry that he looks for the foundations upon which to build up and improve his sources of illumination. To physiology and psychology he looks for guiding principles in adapting and modifying these sources to better meet the physical needs of man. To architecture and to the decorative arts he turns for the means to make these sources of illumination serve not only man's humbler need of material efficiency, but also to stimulate and satisfy the higher esthetic perceptions, and thus, truly to raise the art of lighting to a worthy place among the fine arts.

For any large advances in fundamental engineering practice there must be corresponding discoveries in physics and chemistry, and to important discoveries in physics and chemistry, theory and experiment must contribute. For it is the rule in the exact sciences that experiment and theory must advance hand in hand. If one gets too far ahead of the other, either our experiments become aimless or our theories uncertain.

Thus, theories concerning the nature of light can hardly be unimportant abstractions to the illuminating engineer. This, I take it, is the reason your program builders called at this meeting for a paper on "Modified Views on the Theory of Light."

Now a theory of anything can never be better than the best compromise which can at any time be made with the known facts of observation. It may and does suggest new directions for experimentation. In any given instance, a theory may have much or little weight, depending upon its scope and backing, but however fruitful it may become in predicting new discoveries it should never be held as a fetish.

On philosophical grounds there appear to be only two broad bases upon which a theory of light can rest. Light is due either

[1] Nela Research Laboratories, Cleveland, Ohio.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

to some very small concentrated, or corpuscular thing which is shot out at random from incandescent bodies, or it is a kind of wave motion excited in some universal medium by some kind of activity in the source. These waves or pulse disturbances are supposed to move outward from the source with equal speed and equal intensity in all directions simultaneously. Thus, any particular phase of the disturbance at any given instant will be found in equal phase and intensity at all points over the area of a spherical surface of steadily extending radius. The energy intensity on the wave front must thus vary as the inverse square of the distance from the source.

In these two fundamentally different ways of regarding light, the emphasis naturally falls in two different places. According to the corpuscular or projectile theory, the main interest centers on the two ends of the light ray,—the source and the eye,—medium or no medium lying between is a matter of secondary importance. On the wave theory, on the contrary, the source and the eye are of relatively less importance than the characteristics of the disturbances, and the properties of the universal medium which transmits them. These two types of light theory are as old as philosophic thought; the Greek philosophers discussed them.

The theory of light that we were all taught in school and college was the wave theory, which, from the middle of the last century had seemed quite firmly established. In 1890, following Hertz's brilliant experiments with short electric waves by which the identity of light and heat waves with electric waves had been firmly grounded on Maxwell's electro-magnetic theory of light, there were, with perhaps one exception, no important known phenomena in radiation for which the fully developed wave theory did not give some reasonably satisfactory account.

Thus, an age-old controversy was happily settled as we thought, and we thought it was settled for good. It is still possible that we were right in thinking so, but the astounding progress of experimental physics in the last twenty-five years has done much toward the unsettling of this conviction. Beginning in 1895, Röntgen's discovery of X-rays was quickly followed by Becquerel's discovery of radioactivity, J. J. Thomson's isolation of the electron, Planck's new theory of energy quanta in radiation, and Einstein's theory of relativity,—all within the span of a single decade.

This truly brilliant era of discovery and the developments which later followed it, have brought forward unquestioned facts of observation which it will be hard for the wave theory in its present form to explain. Corpuscular suggestions, which I shall later refer to, begin to appear on many sides. We are forced, therefore, to reconsider these two age-old conceptions of light. Thus, under very different circumstances and for quite other reasons we must face this dual problem which Newton faced 250 years ago.

To my mind the purpose of this discussion is the true purpose of every real discussion, namely, partnership thinking. You will forgive me, I know, for going back at this point over a chapter of high school physics, for some of these matters are quite fundamental and if we are going to help each other to think, we must first agree beyond question upon just what we'll think about. Suppose, therefore, we imagine some simple experiments. To begin with, suppose for the sake of simplicity, we have a light source consisting of just one radiating unit, say a single atom at A of Fig. 1, and assume for convenience that this atom radiates equally well in all directions. Let this atom be surrounded by a hollow spherical shell, B, described about A as a center. Further, suppose the inside of this shell painted white and that it is possible to take an instantaneous photograph of its interior with an exposure not longer than one one-thousand-billion billionth of a second.

According to the corpuscular theory of light which maintains that light is due to isolated projectiles shot out at random from the source, our photograph, when developed, should show the inside of the sphere speckled here and there by very bright isolated flecks of light on a black background. According to the wave theory, however short the exposure, the plate should show the inner spherical surface not spotted, but uniformly illuminated. Were such an astounding feat of photography possible, a single exposure might settle the question at issue. Unfortunately, even the shortest photographic exposures actually obtainable gives us, of course, no evidence at all because the exposure time covers so long an integrated period that the isolated instantaneous corpuscular light spots would also average into a perfectly uniform illumination over the whole sphere.

Hence, as such easy direct evidence is impossible we must seek indirect evidence. You will remember this is just what Thomas Young did in 1801. Using our highly simplified imaginary light source, we can in thought more easily than he did in fact, repeat Young's experiment, thus: Imagine two very narrow parallel slits, D and D′, Fig. 1, cut in the surface of the spherical shell. In the actual experiment these slits should be quite close together. Behind them, let us set up a white screen at K. According to the simple bombardment or corpuscular theory, we should find two bright lines on the screen K directly in line with the slits D and

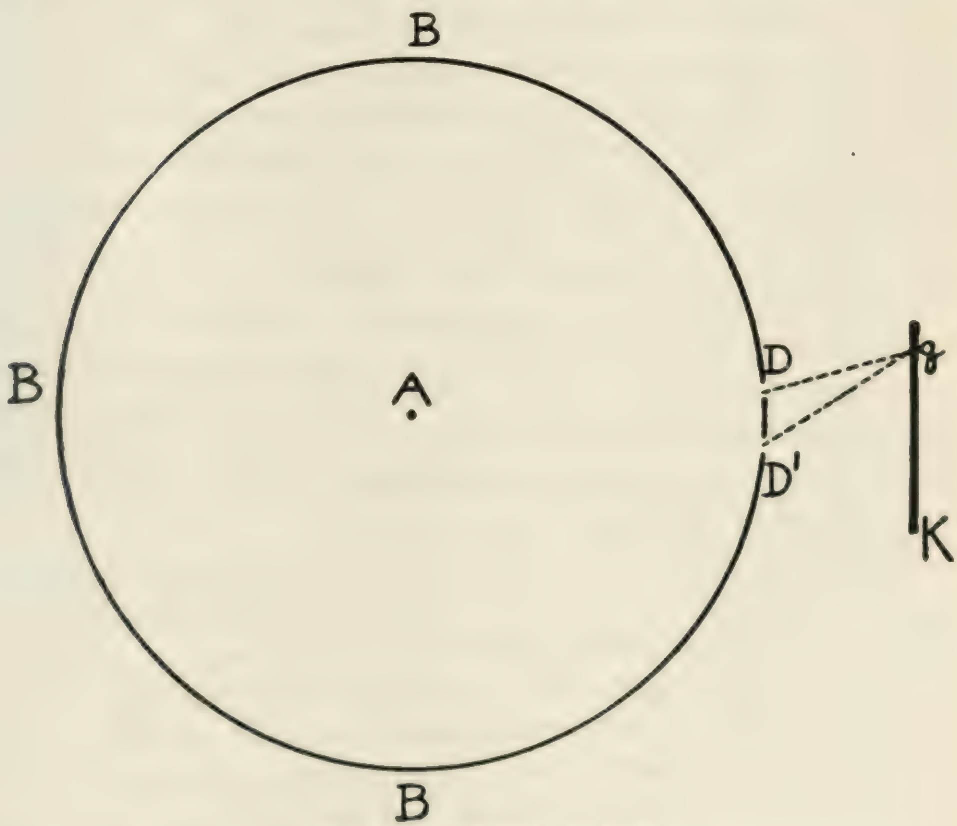


Fig. 1.—Experiment with light.

D′, and the source at A. You will remember what Young actually found and what any of us, if he knows how to, can find for himself by spending an hour in the laboratory, was a whole series of evenly spaced alternating light and dark bands. Most surprising of all, that portion of the surface of K lying directly behind the opaque partition between D and D′ was not a dark band, but a very bright one. This result seems wholly impossible of

explanation on any kind of a bombardment theory, while it is a necessary consequence of the wave theory.

In fact you can easily perform a perfectly analogous experiment and obtain an analogous result by making waves or ripples on any otherwise quiet water surface. Thus, if our sectional diagram, Fig. 1, be thought of as a smooth water surface which we can disturb by plumping in a pebble at A, a wave train will proceed outward from A in extending concentric circles. When this wave train meets the barrier B, any given wave crest or wave trough will strike all parts of the barrier and hence the small openings at D and D′ at the same instant. Through the openings D and D′ very short sections of the wave front will pass and cause these openings to become centers of two independent sets of circular waves. These two independent wave sets will overlap in the space behind the openings in a perfectly definite way. If we now place another barrier at K for these combination waves to splash against, we find spots along the water line of K where waves from D and D′ always come together in step, crest always meeting crest and trough meeting trough. These will be spots of maximum wave agitation. Midway between these points of maximum agitation along K will be spots of no wave motion, spots where a crest from D will invariably meet a trough from D′, and vice versa, thus these equal and opposite tendencies will here always neutralize each other.

The criteria which determine the degree of water agitation along K are simple. If q be any point on this line, then if Dq— D′q is zero or any whole number of wave-lengths, q will be a point of maximum agitation. If, on the other hand, Dq — D′q is any odd number of half wave-lengths, q will be a point of least wave activity. By noting the positions of these alternate points of maximum and minimum wave agitation along the water line of K, it is easy to see how we might roughly measure the actual length of the water waves employed. It was by an analogous method of measurement that Young made the first approximate determination of the wave-length of light. Young's experiment is one of the most fundamental criteria we have for deciding between the rival theories of light. The evidence it gives us is just as good as it ever was, but we have some new evidence which we must consider along side it.

The bombardment theory dominated the field during the whole of the eighteenth century, and even after Young's experiment, it took nearly all of the first half of the nineteenth century for the wave theory to gain an undisputed ascendency over it.

Let us consider a few out of the many recent advances which have made us uneasy and sent us back to re-examine the evidence in a question we had thought for the last 75 years, conclusively settled. The first of our examples arose from an observed curious behavior of X-rays. Now all the evidence we have experimentally and theoretically about X-rays convinces us that they consist of pulses differing only in one minor particular from light, *i. e.,* they are of vastly shorter equivalent wave-length. By a pulse in this case, I mean a fragment of a wave. X-ray pulses according to the pure Maxwellian point of view, would be half a wave-length in extent, corresponding thus in water waves to a single crest without a following trough. This idea of ether pulses is not a new one. Physicists had earlier considered it in explaining the nature of white light. We feel quite sure we know how these pulses originate at the target of an X-ray bulb, but the manner in which they spread, or do not spread, out into the ether is at present most baffling.

To get at this difficulty, suppose we again imagine the simplest conditions for an experiment. In Fig. 2 let B represent the usual X-ray bulb with cathode at K, target and anode at T. Now in the normal working of an exhausted X-ray bulb, negative electrons, thought to be ultra-minute spheres of pure negative electricity, are driven at high speed from the cathode K, or from the region near the cathode down upon the target T. The square of the speed with which the electrons strike the target is in direct proportion to the potential difference between K and T, and hence is under our control. The concave cathode concentrates or focuses this stream of electrons upon a small central spot on the target T. This focal spot is the source of X-rays which proceed outward in all directions from it.

According to Maxwell's theory, the most perfect form the wave theory has yet taken, a charge of electricity when suddenly stopped or suddenly started in motion, or whenever its motion is changed in direction or speed should send out a definite and calculable disturbance or pulse in the surrounding medium. Thus,

the reason why the spot on the target is the source of X-rays is because at this point the flying electrons are suddenly stopped. But according to Maxwell's theory, the pulse disturbance due to each single electron which strikes the target should proceed outward as a spherical wave front in the surrounding medium and thus the intensity of the pulse at any point should diminish with the inverse square of the distance travelled. According to one type of experiment, this pulse spreading out as a spherical wave front does not seem to fit the observed facts.

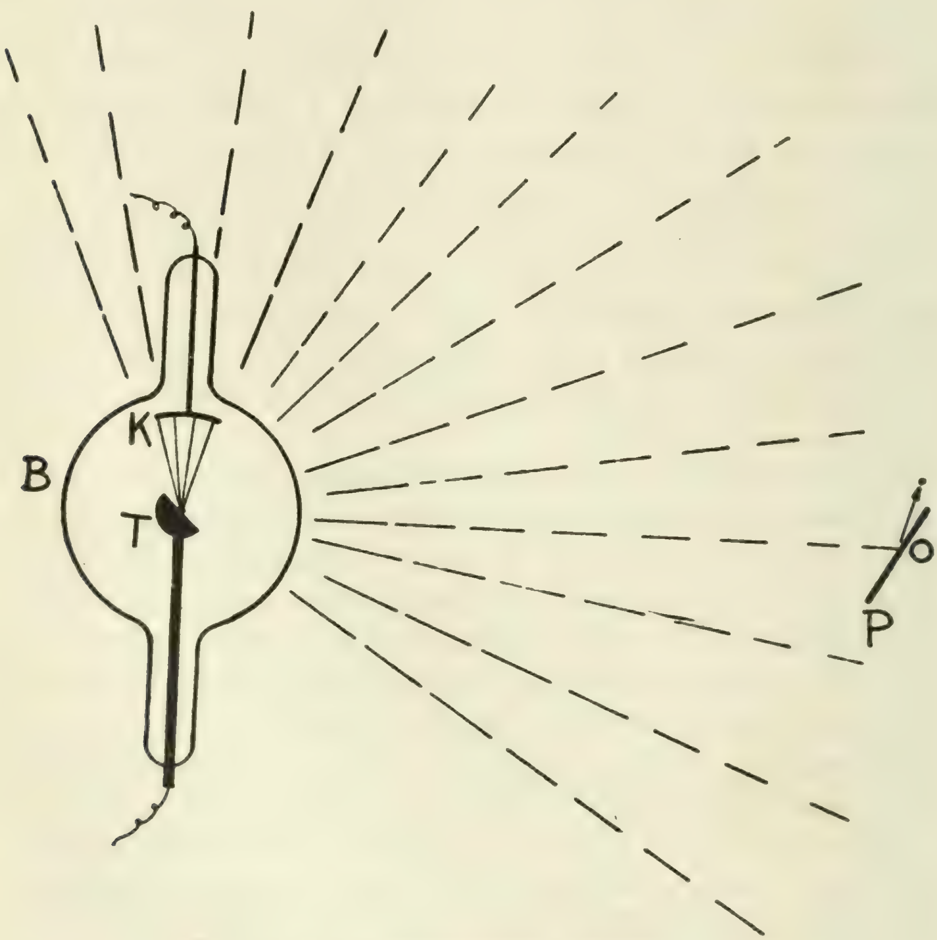


Fig. 2.—Experiment with X-Rays.

It is known that wherever X-rays fall on a metal surface negative electrons are ejected from the surface. It has further been noticed that the speed with which these electrons are shot out from the exposed metal is comparable to the speed of the electrons striking the target in the X-ray bulb which give rise to the X-rays em-

ployed. If we vary this speed, the speed of the ejected electrons varies with it. For a given condition of the X-ray bulb, the number of electrons ejected from the metal plate per square centimeter area per second varies as we should expect it to with the inverse square of the distance separating target and test plate, *but the speed with which the individual electrons leave the metal plate is independent of this distance and hence independent of the intensity of the source as well.* This astonishing result, an unquestioned fact of observation, has found no satisfactory explanation in Maxwell's theory. It points distinctly to a simple projectile character for X-rays. For, consider a single electron striking the target T of the X-ray bulb B, and further suppose that the wave pulse it causes moves outward along the line To, not as a spherical wave front of diminishing intensity but as a compact bundle of energy. At whatever distance away the ray encounters the test plate at o, having lost no energy, it would still be capable of doing the work of hurling an electron out of the metal with a speed comparable to that of the initial electron in the tube which gave it birth. Yet we also get well defined interference phenomena from X-rays which we need some kind of wave theory to explain.

The second new difficulty for the wave theory to which I want to give a moment's discussion is closely analogous to the one just described, but in this instance, the exciting energy is ultra-violet light instead of X-rays. The phenomenon I refer to is called the photoelectric effect. It has long been known that when ultra-violet light strikes upon a polished metal surface, the surface discharges negative electricity. More recently, it has been found that this negative discharge is made up of discrete electrons. The speed of the discharged electrons represents a quantity of energy roughly proportional to the inverse wave-length or frequency of the incident ultra-violet radiation. But again, *this speed is independent of the intensity of the beam.*

Thus, single electrons can here and there be instantly drawn out of a metal plate by ultra-violet light of such low intensity that the amount of energy falling on any electron in the test plate, if computed on the wave front theory, would have to be the slow accumulation of hours of exposure before it reached an amount sufficient to eject an electron with the requisite speed. This phenomenon, therefore, seems flatly against the wave-front theory

and points to a concentration of energy in a very small volume. Whenever one of these supposed energy packages chances to hit an electron squarely it pulls it out with a speed wholly independent of the average intensity of the incident light.

The hypothetical light corpuscles of Newton's speculations were supposed to be minute imponderable particles, more like matter than anything else. The projectiles suggested by the foregoing discussion seem more like packages of concentrated radiant energy, which, unlike parcel post packages, do not spill their contents in transit.

A very large difficulty of quite another kind has arisen in the path of the wave theory as Maxwell left it. In the early nineties there arose a great interest in the distribution of energy in the spectrum as a function of the temperature of the source of radiation. Now the burden of the spectrum on the life of an illuminating engineer and on the life of a physicist is quite different. The engineer is troubled by only a short range of visible wave-lengths, while the physicist is responsible for all wave-lengths from X-rays to the longest wireless waves. If we represent the length of the visible spectrum by an inch, the explored and charted infra-red or heat spectrum alone reaches out to a length of 125 ft.

But to return to spectral energy distribution as a function of temperature; Kirchhoff had shown earlier that if the walls of an opaque cavity with only a tiny hole for outlet be uniformly heated up, the character of the radiation from the small aperture would be precisely the same for the same temperature without regard to the kind of material in which the cavity was made. This independence of material does not hold for the usual sources of light which consist of bodies heated in the open or inside transparent envelopes. Thus, for any given wave-length and temperature, the emitted energy has one value for hot carbon, another for hot tungsten, and yet another for a hot Welsbach mantle, and so on, but if we make cavities in blocks of carbon, tungsten and Welsbach mantle material, and let the rays out through small apertures, these individual differences disappear and Kirchhoff's law holds good. This normal cavity radiation bears the familiar name of black-body radiation, although it has also been called natural radiation, equilibrium radiation, and by several other names.

It was, as I have said, in the nineties that the spectral distribution of energy of black-body radiation for different temperatures

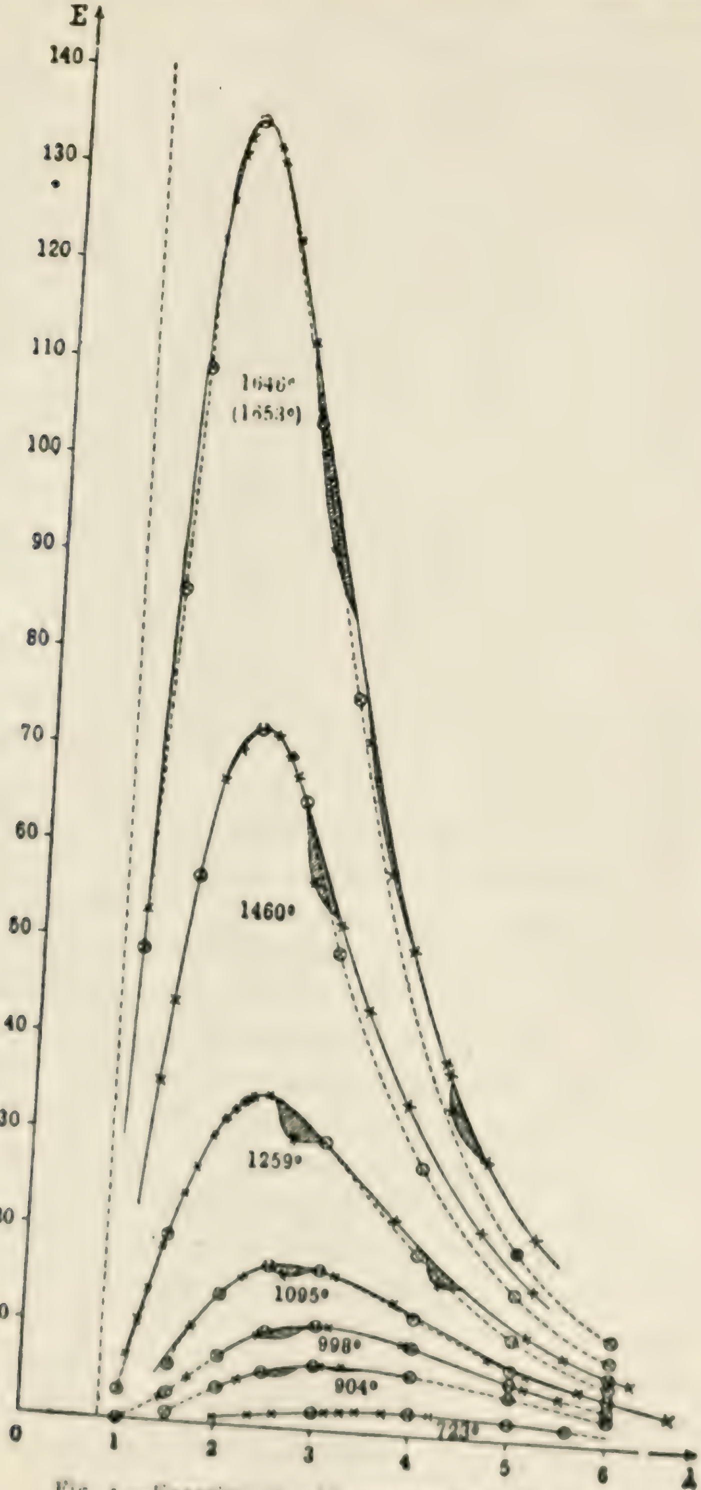


Fig. 3.—Experiments with energy radiation.

began to be actively and accurately studied experimentally and considered theoretically.

The first equation deduced on theoretical grounds to represent the spectral energy distribution for a black body as a function of wave-length and temperature was the work of W. Wien. He based his reasoning on two explicit assumptions; one of them incontestable, the other reasonable. He made a third unconscious assumption which was that the process of emission of radiation was a continuous process. Everybody before him had made the same assumption and nobody dreamed that this view might not strictly correspond with the facts of nature. Our whole classical dynamics had been built upon the assumption of continuity. Wien's theory fitted Paschen's measurements to a nicety. Next, Lummer extended energy measurements to longer waves and found Wien's formula did not fit in that region. This lack of fit is shown in Fig. 3. These curves are the familiar isothermals, abscissæ showing wave-lengths in microns and ordinate the corresponding amounts of energy. The dotted curves are Wien's theoretical values and the full line curves are Lummer's actual measurements. After the publication of Lummer's results, Planck re-examined the theoretical validity of Wien's formula from another angle and pronounced it sound.

In the meantime Lord Rayleigh from an entirely different point of departure arrived at a formula based upon the fundamental principle of the equi-partition of energy. He suggested that his equation might hold for long waves and it did, but it in no way fitted the measurements already in hand for shorter waves. Here was a dilemma. We had two theoretical laws for the distribution of spectral energy from a black body, one of which proved wrong for long waves and right for short waves, the other proved right for long waves and wrong for short waves.

Planck made another theoretical attack, knowing beforehand that he had to get a formula which would be Rayleigh's formula for long waves and high temperatures and would be Wien's for short waves and low temperatures. In Planck's new beginning he considered the electro-magnetic radiation from an enclosed group of electric resonators and in the first instance arrived at Rayleigh's formula and could get no other answer so long as he considered radiant emission continuous.

He then broke away from classical dynamics altogether and assumed that no electric resonator could emit any energy whatever until it had accumulated a perfectly definite minimum amount, or some exact multiple of that amount, then it would radiate that amount forthwith and lie quiet until it had gathered another equal accumulation. This is the gist of Planck's revolutionary idea. Developing it further, he was led to the discovery of a new constant in nature which he designated by the symbol h.

Now the least amount of energy a single atom or vibrator must have according to Planck to radiate anything was found to be hn, where n is the number of vibrations per second which is characteristic of the vibrator. Since Planck's discovery, this mysterious quantity hn, called an *energy quantum*, has spread rapidly, not only through spectroscopy, but has cropped out in the field of specific heats which used to be thought remote from radiation. It has shown itself also in X-rays, in the photo-electric effect, in the radiation resulting from the discharge of electricity through gases, and elsewhere.

These are its triumphs, but it has also played havoc with classical dynamical principles for it raises grave doubt whether we can any longer apply the broad principle of Least Action, or the principle of the Equi-partition of Energy to radiation, except in a statistical way. Here again, and from quite another direction, we have thrust upon us the idea of energy done up in discrete packages. Not only is matter atomic, but may not radiant energy be likewise conditioned?

Another new element has recently come into the theory of light to modify some of our older views regarding it. In 1887, Michelson and Morley tried here in Cleveland an experiment to determine the relative motion of earth and ether. The experiment gave a negative result and this negative result has had far-reaching consequences for it must ultimately be held responsible for Einstein's theory of relativity and all its consequences, dimly seen as yet.

Einstein's theory in its rigorous working out is too vast a labyrinth to be gone into here. Yet, as you all know, it had led its author to a modification of the Newtonian law of gravitation when applied to bodies in rapid motion.

Since the discovery and measurement of light pressure in this country and in Russia twenty years ago, it has been perfectly clear that a beam of light possesses momentum as Maxwell's theory explicitly predicted. One of the consequences of Einstein's law of gravitation is that light possesses not only this proved momentum, but is subject to the gravitational attraction of matter as well. Hence a beam of light from a distant star passing near the sun's edge should be bent slightly inward toward the sun, and the star's position as seen from the earth appear, therefore, very slightly, but still measurably altered.

The first chance to test this prediction after it was made was at the solar eclipse of May 29, 1919. Photographs taken on this occasion of a group of stars near the eclipsed sun, upon later measurement showed the predicted stellar displacements, correct in amount within the errors of observation. This result has been generally accepted by physicists and astronomers alike. This new century has shown, therefore, that a beam of light possesses not only momentum implying *inertia,* but also *weight.* Heretofore, inertia and weight have been the fundamental and distinguishing properties of matter. Now they appear to be properties of light as well.

All in all, therefore, a great deal has happened to the theory of light in the last 25 years. We have discussed together only a few striking points contained in the much longer, fuller story, but enough, I hope to indicate why it is that we speak of the theory of light to-day with much greater uncertainty than a quarter of a century ago. We certainly know vastly more about light than we have ever known before, but the theoretical physicist has yet before him a very hard task and an even greater opportunity in connecting up the new knowledge with the old, and harmonizing both into a comprehensive and authoritative theory of light. Until that great feat has been achieved, the physicist will have to speak gently, almost apologetically, to the so-called practical man who demands to be told in a nutshell all there is to know about light.

DISCUSSION.

LOUIS BELL: I think we owe a great debt to Dr. Nichols for showing the infinite plasticity that has come over physics in the last quarter of a century. It isn't a question of unlearning all

that was learned a quarter of a century ago, but rather adding to it, and co-ordinating with it, as much as had been gathered through the previous century.

The thing to which I want to call particular attention in Dr. Nichol's paper is the way in which we have had brought before us the difficulties which have arisen with our order of work. During investigation we have passed from the comfortable Maxwellian light wave, in one direction to the electro-magnetic wave of the wireless man, and in the other to the X-rays.

The X-ray, only a few years ago, was a mystery. Now, as regards magnitude, we would have, if we had to deal with the wireless man's energy, wave lengths from 500 to 3,000 m. for which space like this hotel is a point, a mathematical point, to all intents and purposes.

We couldn't find out very much about the theory of lighting, as we illuminating engineers know it, if we had to start from a 1,000 m. wave length. We struck the same difficulty with the X-ray. The change in the order of magnitude was too great to grasp until about seven years ago when it was finally co-ordinated with the rest of the system.

Now we are similarly struggling with the mechanism of radiation. If the difficulties which have been injected in the older theory of light have been the difficulties of the mechanism on a minute scale, the difficulty of explaining the larger phenomena by the corpuscular theory is perhaps far greater than in the other case. The trouble is with the minuteness of the mechanism and the thing to which we want to direct our attention is the co-ordination of the so-called quantum of energy, with that which results in which we call light.

We just now want to remember particularly that we are not anywhere near explaining light yet, as regards not only method and mechanism, but order of magnitudes. We are now facing the possibilities of the quantum theory, and so on; we are just as much at sea as Newton was in regard to the *actio in vistaus*. That was the one particular thing he never tried to explain. We don't really know any more about the mechanism of the electron and the positive nucleus than we did of the old phenomena of the X-ray twenty years ago.

We comfort ourselves with the idea that we have gone to the bottom of the theory and then suddenly find that there are more kinds of spectra than kinds of vibration of our assumed electrons.

So we have to confront ourselves with discovering sooner or later, a fineness of structure which will perhaps go as far beyond the present electro-nucleus as that is beyond the physical theory of forty years ago. We are very, very far from getting to the bottom of the thing yet.

G. M. J. MACKAY: How would the results obtained by Dr. Nichols in his experiments on the pressure exerted by light be interpreted in relation to the three theories to which he has referred?

C. H. SHARP: I will not attempt to add anything to the scientific discussion which is going on here. I do want to point out the fact which Dr. Nichols very obviously evaded, that some of the most important discoveries which have led to the modern views which he has placed before us, are discoveries of his own.

When he by isolating and measuring the energy from very long so-called heat waves, hooked up the heat spectrum with the electro-magnetic spectrum, he made a great step forward. When he made the radiometer by which such minute energy quantities could be measured, he made a great contribution to science, and further, when he, at last, succeeded in measuring the pressure of radiation, he more or less completed the links which make up the chain.

JOHN LEUTHOLD (Communicated): As the propounder of the doctrine of "The Fabric of Cosmic Energy," I naturally have read with keen interest and satisfaction Dr. Nichols' statement that the authority of the wave-theory of light in the laboratories of the physicists is waning.

The wave-theory of light thus placed under a mantle of doubt is, of course, that theory of light propagation which finds its analogy in the waves, ripples or undulations produced when any object is dropped upon the surface of a quiet sheet of water. The kind of waves drawn in question are waves proceeding in closed circles from a central point of activity or disturbance.

Against this theory of light propagation there exists, in addition to the evidence slowly accumulating in the laboratories, strong

visual evidence which I here desire to call respectfully to attention.

The excuse for this intrusion is furnished me by an illustration which embellishes Dr. Nichols' printed paper. On p. 564 thereof there appears a figure showing an X-ray bulb and a dotted line representation of the supposed emanations from it. For some reason these dotted lines are drawn as straight lines, or rays, issuing from the central anode or target. Inasmuch as the wave theory of light is under discussion, which was inspired by the spectacle of circular undulations on a sheet of water, why were not the dotted lines drawn as circles around the target?

Has anyone, either designedly or absent-mindedly, ever employed straight lines converging in the point of causation when picturing the effect produced when an object is dropped upon a sheet of water? Has anyone ever seen straight lines employed to visualize on paper the sound-waves proceeding from a bell or a tuning-fork? In both of these instances circular lines are employed spontaneously, almost, in obedience to the knowledge imparted by nature. On the other hand, has anyone ever seen light-emanations pictured by means of circular lines around the spot of emanation? I never have. Light has always been visualized as Dr. Nichols has visualized it—by means of straight lines, suggesting rays or beams. Why should this be so, if there is a particle of foundation for the theory that light-bearing ether-waves are analogous to the ripples upon the face of a pond?

The fact is, that ever since the first man opened his eyes to the wonders of nature, his observations have pictured light as emanating in the shape of sharp, linear rays, beams or shafts. As Dr. Nichols has visualized the emanations from the X-ray bulb, so has from time immemorial been pictured the light issuing from the sun, from every star, every lamp, and from every other source of light.

And not man alone has done so. Nature, by means of the photographic camera, is doing the same thing. As pronounced examples, let any man examine the numerous photographs taken of the sun's corona. I believe these photographs to be alone sufficient to forever rid the scientific world of the ether-undulation theory of the propagation of light.

The latter theory is so unnatural, so artificial, so at variance with visual evidence, that no scientific writer has ever succeeded

in consistently adhering to it. It has converted every treatise on the subject of light into a self-contradictory agglomeration of words and phrases. "Waves" and "rays" battle with each other on every page of the literature dealing with the subject of light.

The visual evidence against the wave theory of light is conclusive, and sooner or later it will win the case in favor of the fabric of all-pervading carrier-rays for all the emanations of light, magnetism, electricity, radio action, etc. The laboratories will do well to get on the good side of the pictorial witnesses in the controversy.

ENOCH KARRER (Communicated): Had Dr. Nichols wished to consume a little more time on this interesting subject, he might have given some speculations as to the exact nature of radiation and matter, such as have been recently given by J. J. Thomson.[1] It may be of interest to state a few of the concepts involved in these speculations that attempt to give a picture of the process of radiating light and other processes of transference of energy.

Two things are postulated:

(1) The existence of particles all of the same kind, moving with the invariable velocity of light in vacuum. These are called mass particles. The mass of electrons and of atoms, is due to these particles; and the mass of radiant energy is likewise due to these mass particles. Dr. Nichols has spoke of the momentum and inertia of light. Light has mass due to these mass particles always associated with radiant energy.

(2) The existence of lines of force, about which the mass particles move with the velocity of light in vacuum.

Now to point out succinctly the nature of light that follows from these postulates—whenever any of the lines of force become closed upon themselves, their ends are no longer anchored to the positive or negative charges, and they may therefore be carried away by a mass particle with the velocity of light through a vacuum.

This concept of radiation as due to looping of the lines of electric force is a well known one in the realm of long electro-magnetic waves. Now, however, we have to think of these loops as carried by mass particles.

Although the mass particles with the looped lines of force

[1] *Philosophical Magazine*, June, 1920, p. 679.

travel with the velocity of light in a vacuum, it seems that it can be shown that the velocity of a pulse of electric force will travel through a medium with a velocity due to the number of electrons which it encounters, because of the secondary radiation coming from the electrons.

Some limit can be set on the size of these mass particles, by considerations of interference phenomena. A wave train of the green light from mercury longer than 400,000 wave lengths can be emitted without change in phase. The energy in this radiation, from Planck's quantum relation, is about ($1/2.4 \times 10^4$) one twenty-four thousandths of that energy of an electron. Then assume that there is one mass particle per wave length of this wave train, or four hundred thousand (4×10^5), so that the energy of an electron is ten thousand million times that of one mass particle, and their masses stand in the same ratio ($.10^{10}$). This gives a fineness of structure of the universe such as Dr. Bell has surmised is necessary.

In general the finer the structure we attribute to the ultimate realities of the universe, the more properties and phenomena can we explain.

E. F. NICHOLS: In reply to Dr. Sharp's direct question, I may say that Planck has shown on theoretical grounds that radiation pressure on the corpuscular theory, using Newton's conception of mass, should be twice as large for a beam of the same intensity as the radiation pressure computed by Maxwell on the electro-magnetic theory. The actual measurements of radiation pressure in this country and abroad give a numerical agreement with Maxwell's value and therefore constitute an added proof of Maxwell's theory as opposed to Newton's.

The evidence from X-rays and the photoelectric effect for a new corpuscular theory of radiation points to projectiles composed not of matter but of electro-magnetic energy. The pressure resulting from a bombardment of radiant energy corpuscles would have the value Maxwell predicted. Hence radiation pressure affords no means of deciding between the wave front theory and the new corpuscular energy hypothesis.

THE HIGH COST OF POOR LIGHTING.*

BY R. E. SIMPSON

When a factory owner receives a bill from the gas or electric company, he feels that he has at least one definite item on which to base his overhead costs. Moreover, he doubtless notes with satisfaction that there has been little if any increase in the service rates during the last five years, and is duly thankful that in this age of high cost of everything, the prices of the gas and electricity that are necessary in his business have remained somewhere near the pre-war level. A closer analysis of the various factors entering into the overhead cost of production may disclose, however, that owing to circumstances that are entirely within his control, he is not getting an adequate return for the money expended. A manufacturer should not be satisfied with his illumination, nor can he definitely ascertain the correct charge for that illumination, until he has proved conclusively that it is impracticable to increase the productive capacity of his plant, or to decrease the percentage of spoilage, the damage to apparatus, the intentional lost time, and the accident rate, by varying the intensity levels or making other changes in his lighting system.

It is not the purpose to discuss all these factors at this time. That has been done more or less exhaustively in papers previously read before this society, and in articles in the technical press. At present our attention is to be directed to the last item,—namely, to the influence of lighting upon the accident rate, and the consequent bearing of the accident rate upon the lighting bill.

It has been definitely established that ten years ago approximately 24 per cent. of our industrial accidents were caused by poor lighting.[1] In the intervening decade much progress has been made in the art of illumination and in promoting the safety of workers, with the result that this percentage has been considerably reduced. The safety-first idea was brought forth, and its influence is now evident over the entire country. This safety movement has wrought such a change in the physical safeguarding of industrial hazards that whereas ten years ago accidents

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] Illumination and One Year's Accident—I. E. S. TRANSACTIONS, 1915, Vol. X, page 868.

occurred in thousands of places where neither guards nor lights were provided, to-day most of these places are guarded so that the presence or absence of light has a relatively small bearing. The last ten years have seen marked progress in the development and use of artificial light-sources, greater attention given to the design and construction of factory buildings in order to secure a maximum amount of natural light, and the gradual introduction of factory lighting codes. The general dissemination of information on lighting questions by various interested organizations during this period has also produced beneficial results, and the larger insurance carriers have played a by no means unimportant part in this work, because a successful compensation insurance carrier must continually study the causes of accidents and devise methods for preventing them. As preventive measures are evolved, the insurance carriers take steps to see that these are adopted and put in force by their policy holders, so that in the lighting field the insurance companies are continually doing missionary work.

A complete survey of accident reports for the past year, such as was made for the year 1910, has not been made; but a rather limited observation of reports, coupled with personal investigation and study, leads to the conclusion that at the present time approximately 15 per cent. of our industrial accidents may be attributed to improper illumination. Even a cursory study of the subject will reveal the fact that of late years only a minor percentage of what we may term lighting accidents are due to *insufficient* illumination. We find, instead, that accidents that may be charged to faulty illumination are mostly caused (1) by continued eye-strain with its general detrimental effect on our physical well-being (and this is recognized as a distinct moral hazard), (2) by sporadic but more acute eye-strain, and (3) by glare,—all brought about by *improper use of light-sources.* From this we may fairly conclude that the increase in the knowledge of the general public concerning proper illumination has by no means kept pace with the development of the art. It is highly desirable, therefore, to pay greater and more specific attention to the problem of the proper use of light-sources, as well as to the question of raising intensity-standards.

If we admit that 15 per cent. of our industrial accidents are due to the misuse of light-sources, what does this represent in

financial and economic loss? If we knew definitely the number and nature of the accidents that occur each year, and also their cost, a simple calculation would give us, in dollars, the total loss chargeable to poor lighting. Unfortunately there is no central agency for gathering data of this kind, so that we must pick up our information here and there, piecemeal, from reports of various bodies such as State Labor Departments, Industrial Commissions, and insurance companies. Compilations from these different sources are likely to contain duplications, and there will surely be important omissions. Bearing this in mind, however, we shall find that there is a fairly close agreement among various investigators to the effect that there are each year more than two million non-fatal industrial accidents causing loss of time. According to the standard accident-severity table, 95 per cent. of these accidents would be classed as temporary total-disability cases, causing an average time loss equivalent to two and one-half weeks per accident. One-tenth of one per cent. would be classed as permanent total-disability cases, with an equivalent time loss of 850 weeks per accident. The remainder would be considered permanent partial disability cases, with equivalent time loss of 190 weeks per accident. Conservative estimates of fatal accidents place the number at 25,000 annually, with an equivalent time loss in excess of 850 weeks per accident.

This is hardly the place or time for giving a detailed explanation of the constants that are here employed in connection with accident statistics. It might be well to say, however, that for the purpose of facilitating calculations of this sort, in which injuries of several types are involved, it is customary to reduce all the data to a single basis,—and it is most convenient to adopt, as this basis, the loss of time that would be financially equivalent to each type of casualty. We say, for example, that a fatal accident is equivalent, on an average, to a time loss of 850 weeks,—meaning thereby that the total cost, in money, would be the same, whether the man lost 850 weeks or were killed. And please note that the significance of these figures lies in the fact that they represent sums of money that *must be paid out,* in some way or other,—indirectly if not directly,—and mainly by the employer.

Our conception of the total economic loss that the foregoing figures involve will depend largely upon the unit-costs with which

they are associated. If we conservatively estimate \$20 as the average weekly wage, and assume that \$20 per week are needed in addition to cover medical attendance, hospital charges, loss in production, insurance, and the various other items that enter into the cost of an accident, we find the total annual cost, in round figures, approximates \$2,000,000,000,—the part chargeable to poor lighting therefore being about \$300,000,000. This is a sum in excess of our yearly industrial-lighting bill, and hence we see that the misuse and inadequate use of lighting facilities in industry cost more than the light itself.

Although we are accustomed to-day to think and talk in millions and billions, most of us can still grasp the essentials of a discussion based upon hundreds and thousands. It may be of interest, therefore, to consider the lighting bill as rendered by the utility company to a typical plant, and see how this bill is affected by the accident-factor. To do this, we must make certain assumptions, but these can be realized in fact in any industrial center. The factory, we will say, has 1,000 employees earning an average of \$40 per week each, the annual payroll therefore being \$2,080,000. An average of 100 watts for lighting is allowed for each workman, but there are many faults in the installation,—such as lack of reflectors, poor distribution, glare, and specular reflection. Assuming that the lamps are burned three hours per day, during a year of 300 working-days, and that a rate of five cents per kilowatt hour is charged, the lighting bill will be \$4,500 per year, or an average of \$375 per month.

Compensation insurance premiums are based on the amount of the payroll, and the rate is determined by the accident experience of a given industry, modified by the experience of the particular plant under consideration. With a rate of one per cent. the premium in the case under consideration would be \$20,800. The insurance carrier might pay the claims resulting from two accidents per month (on an average), and meet their own overhead costs, and still have a slight margin of profit. An experience of three accidents per month, one-third of them due to poor lighting (a not unlikely event), would leave the insurance carrier no option but to increase the rate by 50 per cent. The premium would then be \$31,200,—an increase of \$10,400, or an average of \$866 per month. We see, then, that the factory owner, in

this example, is paying the utility company $375 per month for illumination, and the insurance carrier $866 per month (or nearly two and one-half times as much), because that illumination is not sufficient to permit his employees to work in safety. The cost of his illumination is therefore increased to $1,241 per month on account of this one item.

Manifestly this is not a happy condition for any of the parties concerned. As a representative of an insurance carrier, I can say with good grace that we sincerely desire to prevent accidents, —and in fact this is an important part of our business. The triple purpose actuating this work is (1) to reduce accident claims, thereby (2) reducing the premiums, and (3) reducing suffering.

This $866 per month does not serve a progressive purpose. At best it merely assists in restoring that which our misuse of a modern convenience has damaged,—that is to say, an injured worker. If part or all of this sum could be devoted to eliminating the cause of the accidents by improving the illumination, the workmen would be benefited through the safer working conditions, the owner would be reasonably certain to increase his production, decrease his spoilage, and have a steady working force, the central station would increase its revenue, and the insurance carrier would not be under the necessity of increasing its premium rate.

A paper presented at the last convention by Mr. R. O. Eastman[2] gives information which suggests a line of action calculated to materially improve our industrial lighting. Mr. Eastman reports that a majority of the executives interviewed during the course of his investigation had little or no conception of what constitutes good lighting. It appears that in their perplexity 45 per cent. of them turn to the retailer and jobber for advice, and less than 10 per cent. to the central station. In the matter of designing or changing the installations, the retailer and jobber have charge of 40 per cent. of the cases, and the central station only 4 per cent. There is a hiatus between the desire for better illumination and the fulfilment of that desire, in which the central stations play an inconspicuous part. Strange as it may seem, the central stations are apparently content to permit outside interests to design and install the apparatus by which their product—elec-

[2] TRANSACTIONS of I. E. S. 1920, Vol. XV, page 77.

trical energy or illuminating gas—is converted into illumination, which, in the last analysis, is what their customers are paying for. Once the installation is completed, the contractor withdraws from the scene and the central station maintains contact chiefly through meter readings and bills,—and possibly complaints.

There is a feeling among the officials of central stations that they do not care to encroach upon the domain of the contractor, retailer, and jobber, although they do that to some extent in the disposal of household appliances. There is considerable difference between encroachment and co-operation, and there is great need for the latter. In the past, contractors and jobbers have not been very aggressive in securing lighting-installation work, nor are they strenuously exerting themselves to obtain such business at present. They are not, as a rule, employing soliciting lighting experts to canvass for lighting business. They have been content to assume a receptive or "Barkis-is-willin" attitude. This may be accounted for, in part at least, by the fact that although the contractors and jobbers supervise 40 to 45 per cent. of the lighting installations, they do not by any means make up that percentage of the total membership in the Illuminating Engineering Society. If they could pool their interests with the central stations, and all could agree upon standards of illumination, upon methods of soliciting business, and upon the apportioning of the expense, material progress could be made. The factory owners and workers would profit in many ways; the central stations, the contractors, and the dealers would increase their business; and the economic loss to the community would be decreased.

CENTRAL STATION EXPERIENCE IN THE IMPROVEMENT OF FACTORY LIGHTING.*

BY J. B. WILSON.

It has been proven with absolute certainty that everyone prefers good illumination whether it be in the home, office, or factory. But how many factories or industrial plants to-day have a modern lighting system? For example, will the average manufacturer when planning the erection of a new plant, or an addition to his present plant, give lighting the consideration it should have? It has been our experience that in almost every instance the material to be used for erection, the kind of machinery to be installed, etc., will be given most careful consideration, but very little thought indeed will be given to lighting. In most cases the lighting is turned over to an electrical contractor whose interest centers principally in wiring and equipment, and who will place outlets as he thinks best for general illumination. The results, in the average case, I believe need not be elaborated upon at this time.

In the past we have criticized the general manager or the one in charge of the plant, for not giving lighting more serious consideration. We have criticized the electrical contractor or the architect for not laying out or specifying a proper lighting installation. But have we been fair in this criticism ? The general manager has a million and one things to think about and will naturally turn electrical work over to someone in his plant or to a contractor who is interested only in the operation of the electrical equipment in the plant. The average contractor, architect, or electrician has not as yet been sufficiently educated in the matter of illumination and is therefore not in a position to render a lighting service in the full sense of the word. To even the architect or the factory superintendent, the matter of foot-candles, lighting intensities, etc., is so much Greek. There is an obvious responsibility which someone should assume in each community for carryng on lighting educational work. Every central station sells light and therefore this responsibility naturally falls to their lot.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

During the month of January, we had a survey made of the lighting situation in Massillon and vicinity and after the subject had been discussed with several of the industrial heads it was found that it would take months to bring the industrial lighting standard in this town up to the proper plane, both quantitatively and qualitatively, by the more or less slow method of trial installations. While in some instances we arranged with a factory superintendent to install a trial installation, the application of this method in every industry in the city was prohibitive from the standpoint of cost in money as well as time.

While we were casting about for a solution to our problem, we heard of a demonstration of industrial lighting at Nela Park, which probably has been viewed by many here present in the various localities where it has since been installed—a demonstration in which a number of types of lighting are shown, the different steps in illumination design clearly pointed out, and the advantages of good illumination both seen and felt. This seemed to offer the solution of our problem. Arrangements were made to take a number of the factory heads to see this and other demonstrations at Nela Park and to spend the day in studying lighting. We believed that if this program could be carried out, we would accomplish in a day what would ordinarily take years.

Invitations were extended to the men in the different industries whom we wished to take with us. Forty-nine of these agreed, other things permitting, to make the trip when the program was laid before them. On the day of this little excursion, thirty-seven were present. A full day was devoted to discussions and demonstrations of lighting with the industrial lighting demonstration forming the climax of the day's program. The details of this day's program are not of particular interest at this time, but it is of interest to know that even men 65 to 70 years old said they had been taught more about illumination in six hours than they had learned in their lifetime before. There was nothing in the day's program which could in any way be construed as an effort to sell anything or to induce anyone of the party to make changes in his plant. The trip was a pleasure trip with education as its objective, and not a business trip in the ordianry sense of the term.

Central station representatives will be interested in the fact that the total cost to us of this trip was $128.00 which we charged to advertising, and as to whether this was a profitable advertising expenditure, we will let the figures cited later decide.

The following day the manager of the Enterprise Aluminum Company called us on the telephone and asked if we could send down one of our men to look over their lighting system which was just being installed. Arriving at this plant, we found that the lighting had some time before been turned over to a contractor with instructions to install a complete system. They were installing glass reflectors with 100-watt clear mazda C lamps and were getting 1.2 foot-candles on the working plane. When we had made different recommendations the head of the plant said that he had realized the minute he got back that they were installing the wrong equipment and that it would be a matter of only a short time before they would feel the necessity for changing over their entire system. He, therefore, accepted our recommendations, ripped out the entire installation they had just put in, and had his own factory electrician install the lighting system we laid out. In this plant we recommended r.l.m. reflectors with 200-watt bowl-enameled lamps. After this installation was completed, they were getting 14 foot-candles with an increased wattage of 53.4 kilowatts. After the installation was completed, Mr. Held, superintendent of the plant, wrote a letter in which he stated that they were very proud of the lighting installation and truly believed that they had the best lighted aluminum plant in the country.

A few days after our return from Cleveland, while passing the Massillon Foundry and Machine Company and talking to the superintendent for a few minutes at the door, I noticed several men working in the shop painting the side walls, cleaning lighting fixtures, etc. The superintendent asked me what I was smiling at, and I told him that our little trip a few days before must certainly have made an impression. He had given instructions to have the side walls painted a light color and had appointed two men in the shop to see that the lighting fixtures were cleaned weekly.

Among other examples I might cite, is the Peerless Drawn Steel Company, one of Massillon's largest steel plants, who had been

using tin reflectors, 200- and 300-watt mazda lamps, 60-watt carbon lamps, etc., throughout their entire plant. We have just completed an installation of eighty-nine 750-watt lamps used with r.l.m. reflectors. Within the past three months, the wattage in this plant has been increased 105 kilowatts. The head of the plant stated that he intended relighting the entire plant, he was so pleased with the work that had already been done. In this plant, they are getting between 15 and 16 foot-candles.

The Bean Spring Company, makers of automobile springs, have just completed a new installation with an increased wattage of 33.2 kilowatts, and are getting between 21 and 22 foot-candles.

The Independent, the evening newspaper of this city, had us lay out an installation for them immediately upon our return from Nela Park, and carried an advertisement on the front page for some time which read as follows:

> "We have just completed our new addition. We pride ourselves in having the best illuminated press room in Ohio; if you don't believe it, come and look."

We have had any number of manufacturers come to us and ask us when we intend having another trip similar to the one already mentioned, stating that they regretted exceedingly that they were unable to go on the previous trip, but that they had heard so much from the men that did go that they certainly did not intend to pass up the next opportunity.

Before closing this paper, I will give a few comparisons which will be of particular interest to the man interested in central station sales. From January to July, 1919, inclusive, we added in industrial lighting 68.5 kilowatts. During the same period in 1920 we added 431 kilowatts. The added kilowatt load in lighting for 1919 burning on an average of 5 hours a day, or 150 hours a month, would bring us an added revenue of $10,800 a year. With the increased wattage of 1920, figuring the increase on the same basis, it would bring us a net revenue of $62,964 a year. During the first seven months of 1919, we sold 39 fixtures for a total of $535.72, with a profit of $185.81. For the first seven months of 1920, we have sold 1,063 fixtures for the sum of $6,016, with a net profit of $985. It can easily be seen from the experience we have had that it pays the central station to go after the

lighting business. I remember a year or more ago that, when this lighting question was taken up with us by one of our New York officials, I stated that the lighting opportunities in our vicinity were very small as every factory I knew of had its own electrician, bought its own fixtures at wholesale, and that we had very little chance of breaking in; also, that we had run lighting campaigns on commercial fixtures for the past several years and that every store in the city was pretty well equipped. But since we have gone after industrial lighting, I can easily realize that this New York official had given the matter more thought than we had.

After going into the lighting situation, it has been proven that electricity is not only in its infancy, but industrial lighting has just begun. What prevailing intensities will be five years from now is largely a matter of conjecture, but there are not lacking reasons for predicting that ranges of intensities far beyond what we are thinking of to-day will come into use. Being fully convinced of the value of demonstration as a means of selling the better lighting idea, we have installed in one of the rooms of our offices a small installation showing types of industrial reflectors, lamps, window reflectors, etc. The entire cost of this demonstration has been approximately $60. We find it much easier and more economical to demonstrate to a man what we are recommending than to make trial installations.

In the past seven months we have more than tripled our lamp sales and we also find that we are getting away from small lamps. In most industries that had been using 25-, 40-, and 50-watt lamps over their benches, these small lamps have been eliminated and in but very few cases we are now recommending new lamps smaller than 100 watts.

I sincerely believe that every central station, contractor, architect, or anyone interested in lighting work should have a foot-candle meter. For three months we have had a lighting meeting two nights a week with our entire sales force, and we feel that any one of our salesmen can lay out a lighting installation without any difficulty. We have brought the architects and the electrical contractors in our vicinity into our fold, so that they are bringing their plans to our offices to have the lighting laid out. The question has been brought up by various central station men

that they do not sell fixtures, or do wiring work. I might say in this instance that we do no wiring of any kind, house wiring or commercial, but turn this work over to some contracting company. We make the lighting layout on their blue prints and get an estimate from the contractor for doing the work, but in most cases we find the industrial plants have their own electrician, and all we need to furnish are reflectors and lamps.

In Massillon proper, we have approximately fifty-two plants which could be termed factories or industral plants. Of this number, we have installed complete lighting systems in seven, and are working on nine more. We have also been requested to make lighting layouts for eight others.

The work we have been carrying on has been promoted during the very worst period of the year, on account of short burning hours, and most of the factories feel they are not in need of light until the fall. I believe that by October 1st, we will have at least 70 per cent. of the factories and industries of Massillon interested in better illumination for their plants.

I might say in conclusion that through this lighting work we have become better acquainted with the working heads of the industrial plants. There is a fine feeling of mutual satisfaction because we feel and they feel that we have rendered them a distinct service by giving them ample illumination properly laid out.

DISCUSSION.

DAVIS TUCK: The conclusion on page 584 is misleading. When 100-watt lamps were used with one kind of reflector the illumination was 1.2 foot-candles. Installing another kind of reflector gave 14 foot-candles. Doubling the wattage should raise the foot-candle value to approximately 2.5 but it is inconceivable that one reflector would differ from another in efficiency by over 1000 per cent. I think there must have been more lighting units installed as well as doubling the size of the lamp in each lighting unit. The author leads one to believe that the large gain in illumination was made simply by doubling the wattage and using a different type of reflector.

J. B. WILSON: Answering Mr. Tuck, that is due to the installation of more reflectors and more lamps. In other words, due to laying the installation without proper spacing of glass

reflectors, you are not going to get the proper foot-candles, but if you select and arrange the equipment properly, you are going to get the foot-candles needed.

P. S. MILLAR: Mr. Wilson has brought before us one solution of central station lighting problems that many of us have recognized for years, but haven't seen realized in service. I don't doubt that the activities that Mr. Wilson describes have very great value to the industries of his town and that if he tried to do it he would find it impossible to take out the superior lighting installations that have been put in those plants. General experience has been that once improved lighting has been installed all efforts made to remove it for comparative data purposes, have been unavailing. It has been impossible to get any comparative figures because the managers won't allow the old installations to be substituted. If information concerning these experiences could be disseminated it would be a good thing for the industries of this country.

Those of us who have devoted some part of our lives to the study of the illumination problem, perhaps smiled a little when we read, "Our entire sales force, we feel, can lay out a lighting installation without any difficulty." Mr. Wilson's confidence in the simplicity of the problem is one that some of us at least don't share. Nevertheless, I don't doubt that Mr. Wilson's salesmen can go in and bring about improvement in the average plant.

G. S. MERRILL: If those engaged in the improvement of lighting conditions would devote but a little of their time to following up and reporting upon the results they accomplish, as Mr. Wilson has done, the lighting industry would soon have accumulated a fund of information of great practical value.

Reports of the extent to which lighting betterments have improved working conditions, as shown by increased production, decreased spoilage or fewer accidents would be particularly valuable. While it is not to be expected that every factory manager would have actual figures available bearing on these points, yet it is not unlikely that, if the lighting has really improved conditions, many of them would be willing to express their satisfaction and, perhaps, point to specific instances where the benefits have been most apparent.

Mr. Wilson, in estimating the kilowatt-hour consumption of the old and the new installations has assumed that both would be used on the average of five hours a day. I believe that as people begin to appreciate the real value of light they will use it more freely throughout the entire day. Moreover, an installation which gives on an average but one or two foot-candles would hardly be used as many hours a day as one giving higher intensity, because it would have to be fairly dark outside before the low intensity installation would produce any appreciable effect. His estimate of the increase in revenue would, therefore, I believe, be conservative.

F. C. CALDWELL: In connection with this interesting story of the work in Massillon, mention should be made of the excellent work being done by the Committee on Illumination of the Ohio Electric Light Association. For two years this committee has been urging upon the central stations of Ohio the importance of industrial lighting, and the remarkable results attained in Massillon may be regarded as of the harvest from their planting.

K. FITZPATRICK: The best way to introduce higher intensity lighting installations is by a demonstration. During a meeting in Dayton of the Ohio Electric Light Association and representatives of the Ohio manufacturers as well, we had a demonstration comparing favorably with the one at Nela Park. In fact, it was through the men at Nela Park that we were able to do it successfully. The central station must be very active in following up those interested. We have obtained some good results. In the plant of the Delco Manufacturing Company manufacturers of Delco ignition systems, intensity has been increased from 4½ to 18 foot-candles. The minimum intensity to-day is 14 foot candles. Another plant with the same work have similarly increased their lighting intensity. A remarkable case is that of Crawford-McGregor Company, manufacturers of golf sticks, probably as old and out-of-date a factory as could be imagined and probably one half of one-tenth of one foot-candle, increased now to a minimum of 8 foot-candles and have other installations of more or less the same nature. The big thing is to make a proper start and it follows that it would probably be a good idea to continue a small demonstration room if space is available for the purpose.

J. B. WILSON: In closing the discussion I wish to say that we are very grateful to Nela Park people for the help extended to us. We have tried every method known to us to interest the various industries in good lighting, and find the best plan is to get them to look over the demonstration at Nela Park, or failing that, to install a local demonstration. It is important to have the management of each industry view this demonstration and the telephone may be used to make personal appeal in each case.

SOME OUT OF THE ORDINARY APPLICATIONS OF INDUSTRIAL LIGHTING.*

BY SAMUEL G. HIBBEN.

The illumination of industrial plants has been fairly well standardized of late, yet nevertheless one meets an occasional peculiar problem, or observes some extraordinary condition that calls forth a bit of mechanical ingenuity mixed with illuminating engineering that is not based upon precedent. Such out of the ordinary lighting applications are not properly classed as freaks; they are special solutions for particular requirements and must be considered simultaneously with the more standardized and more easily solved problems of general overhead lighting, or common broadcast, or simple local illumination.

It is with the practical application of lighting appliances that the factory engineer or superintendent is concerned. Useless indeed is a theoretical hanging height of a reflector as recommended in a manufacturer's catalog if such reflector position is below a traveling crane. Futile would be an installation of the most perfect reflectors and fixtures if it were discovered that acid fumes were rapidly consuming them. Costly would be the most optically efficient lighting installation if exposed lamps were found to increase fire hazard and raise insurance rates. With the complexity of conditions of a large industrial plant the variety of circumstances affecting the design of the lighting system causes illuminating engineering to become one part lighting experience, one part electrical engineering and one part mechanical genius, with emphasis upon the latter.

No lighting engineer can foresee all the peculiar lighting requirements of any industrial plant, and no paper as brief as this one can do more than touch upon several fixture adaptations that have been used to meet these requirements. Perhaps the industrial operators will recognize among the examples that are mentioned here an application that can fit their conditions, or some may profit from a survey of what other operators have done under similar circumstances.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

There is almost no end to the number of unusual applications of lighting equipment in factory and mill work. Most of the examples mentioned herein are taken at random from among typical manufacturing plants, and to a large extent are illustrative of means that have been used to supplement the well-known and acceptable forms of common industrial lighting. These latter methods have been or are being broadly discussed before the Society and will not be referred to here.

There should be no misunderstanding about the desire to simplify all industrial lighting installations, and if it will be borne in mind that these special applications are just what the term indicates, *i. e.,* are designed to meet special needs, then the plant engineer will better understand that his aim should be to take care of his illumination as far as possible through a simple, standard, general overhead lighting system and to use any of these special schemes only where conditions actually demand their use.

One of the first problems that is met is the avoidance of traveling cranes, and the location of lighting units where same will be clear of but accessible from the crane itself. One simple way of doing this in a conduit installation is shown in Fig. 2. The strap-iron bracket fastened to the bottom member of the ceiling truss is used to support the conduit, as well as the reflector. If using an enameled steel reflector the socket could be attached directly to a condulet fitting on an outlet box. However, in this case a glass reflector makes it advisable to use a screen-wire protection that is attached to the reflector holder and in turn supported from the bracket by two short lengths of safety chain. Adjustment of these chains places the bottom of the reflector on a level with the bottom of the truss. Fig. 1 shows a similar scheme, where the additional use of a stage connector may be noted, thus allowing the entire unit to be connected and unhooked and removed to a safer place for cleaning, a clean one being immediately substituted.

Sometimes, in an open wiring installation, it is a simple matter to bolt a piece of strap iron between the two angle irons of a roof member, and attach the reflector socket thereto, giving this piece of strap iron any tilt that is desired. In Fig. 3 this means of supporting an angle reflector is shown.

It is interesting to note in this same installation (Fig. 4) how

angle reflectors are successfully employed in a general overhead system to light a shipping platform, instead of the more usual use of ordinary deep bowl or r.l.m. reflectors, thereby obtaining large horizontal components of light (note angle of shadows in bins) and a limited light on the tracks and side walls. As in this case, two rows of angle reflectors with crossed beams, often give better results than the same number of symmetrical downward pointing reflectors.

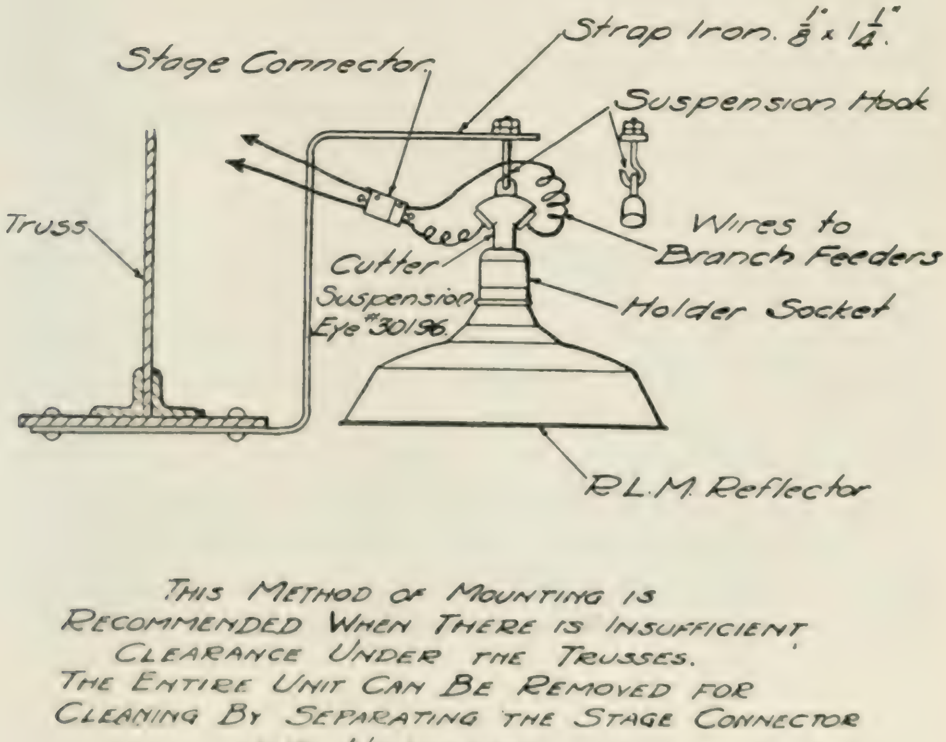


Fig. 1.—Method of mounting reflectors.

In addition to the reflectors for general illumination that may be supported above a crane as mentioned, some mills desire higher foot candles upon limited areas or on certain machines such as a large bed-lathe or a blooming roll, and use a special unit whose position is either fixed or adjustable laterally as suggested in Fig. 5. One plant employs flood-light projectors (with standard mazda C lamps since the concentrated filament flood-light lamps

are unsuited to tip-downward position of burning) mounted in this way. The units are pulled in to a runway for cleaning, and are allowed to run out by gravity to best illuminate any special work upon the floor.

The development of an extension metal sleeve applicable to small flood-light projectors now enables these units to accommodate the standard large mazda C lamps, and while not giving so close a concentration of beam, yet enables these reflectors to be used in any position and hence extends their field in factory and mill lighting. In addition to an application as mentioned above, such a flood-light unit when mounted on a crane-cab and manually adjusted by the crane operator illuminates an object which the crane is picking up or a spot where a heavy casting is to be deposited, and forms an excellent supplement to general overhead lighting.

Instances are frequent where a crane makes it difficult to mount reflectors from the roof in the regular way, and the natural solution is such a use of flood-light projectors as Fig. 6 indicates. Sometimes, also, the fire hazard in a flour mill or cotton press, as Fig. 7 shows, necessitates flood-lighting rather than the usual open style of metal or glass reflector, and the field for this rather out of the ordinary lighting application is large. Dangers that arise from explosive gases are sometimes sufficient to call for flood-lighting from a safe distance, and this reason, coupled with a good light control, justifies the flood-lighting applications similar to that shown in Fig. 8.

Every factory operator knows of the tribulations that arise from the common drop cords used in local lighting, and endeavors to devise special means to reduce their number or their length, or to protect them from abrasion and consequent shorts. Such local cord drops or extensions soon become badly worn and hazardous. Where extension cords are required there are several types of automatic extension reels, whose use is shown in Fig. 9, that will keep the excess wire reeled up and out of harm's way. Such fixtures allow the lamp to be placed where desired, by merely pulling out the cord, and after use, a pull on the cord causes a spring-actuated reel to take up the excess wire.

3-54'

Fig. 2.—Method of supporting a reflector above a crane-way.

Fig. 3.—An adjustable strap-iron support for angle reflectors.

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Fig. 4.—Showing crossed beams of light from angle reflectors, in lighting a shipping platform.

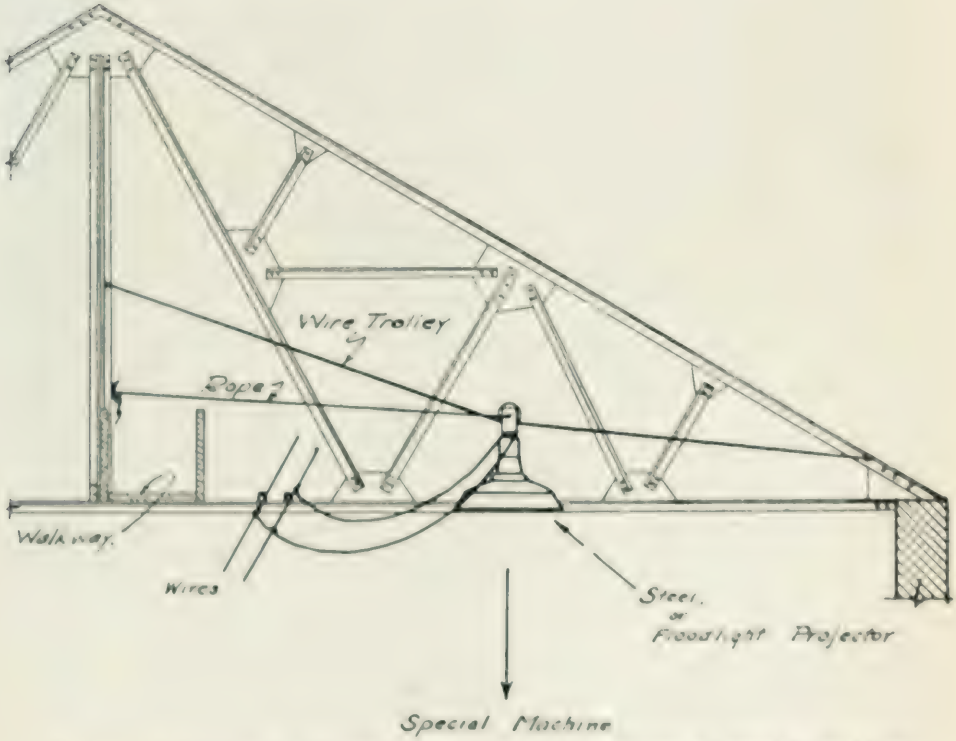

Fig. 5.—A laterally adjustable unit for the illumination of special machines.

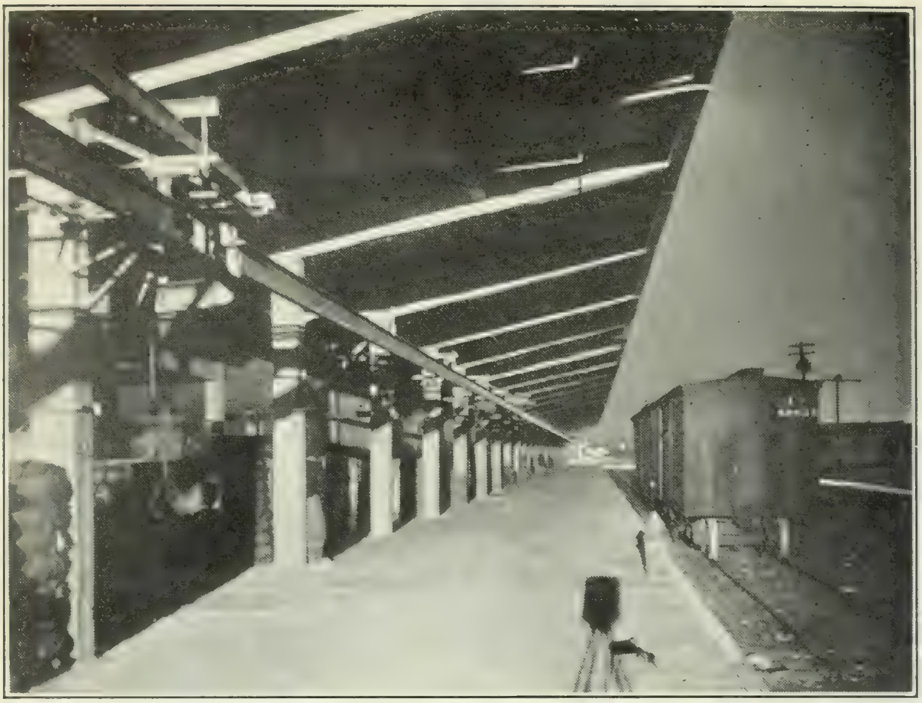

Fig. 6.—Flood lighting of a shipping platform where a loading crane interferes with ordinary fixtures.

Fig. 7.—Flood-lighting a cotton press, to avoid fire risks.

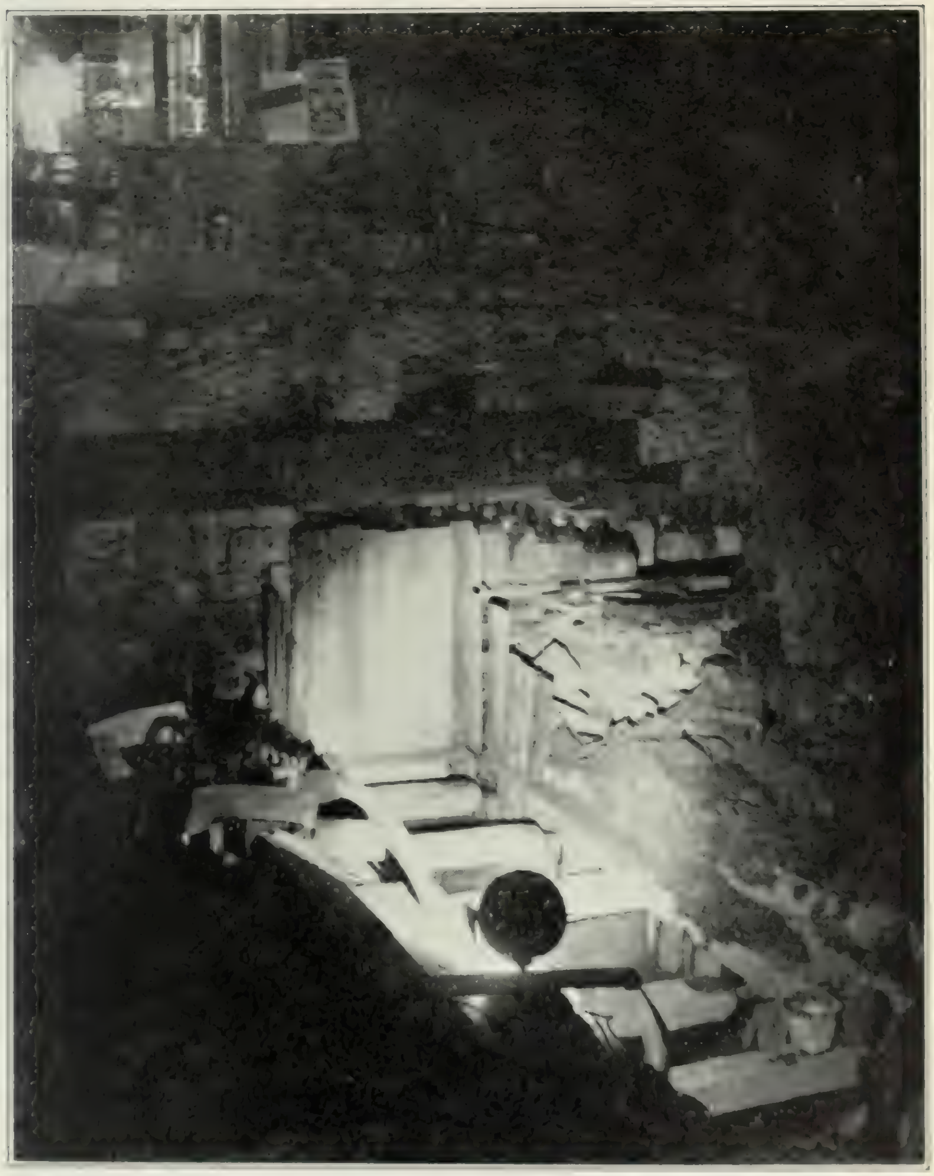

Fig. 5.—Explosive gases, and obstructions call for safe lighting from a distance.

Fig. 9.—Automatic extension reels, for local lamps.

Fig. 10.—Opal glass tops on metal reflectors, furnishing considerable ceiling illumination.

Fig. 10 illustrates the use of a new unit, the metal reflector with an opal glass neck. In factories of this sort, where the floor and general interior is dark, and where the need is felt for a small amount of upward diffused light to allow of inspection and repairs of shafting and belting, this type of fixture is a solution to the problem of general illumination with a minimum of reflector breakage. Similar results will of course result from prismatic glass or dense opal glass reflectors, although their breakage must be carefully guarded against. (See Fig. 2.)

Concerning the matter of breakage in industrial lighting, attention is called to a special form of protection for large glass bowls, shown in Fig. 13. The wire guard is an essential part of the fixture, when the installation is made in high positions in the factory.

One of the most interesting of the unusual lighting applications is found in the equipment of acid and explosive plants. Quite frequently the corrosive fumes will destroy the ordinary exposed unit, and extra protection must be provided as shown in Fig. 11. Here an extra metal reflector is fitted with a glass bottom, and completely encloses the secondary glass or enameled steel reflector, lamp and socket.

The wiring in powder plants and munition warehouses should be on the outside of the buildings, preferably exposed for easy inspection, and this calls for unusual fixtures, similar to those shown in Fig. 12. One large explosive plant uses a box, asbestos lined, containing the lamp, reflector, and receptacle, and inset in the building wall at an angle depending upon the machine positions. Occasionally in particularly dangerous locations, such as one finds in parts of flour mills, powder mills, or where corrosive acid fumes are prevalent, the engineer uses a metal receptacle-box set into the partitions, as shown in the illustration. The glass front safely protects the lamp, and may be removed for lamp renewals. All necessary ventilation is provided through the conduit.

A quick rough and ready means of providing adjustable local lighting is often a problem to the plant engineer. Many solutions are met with, some worse than others, but as an example of an easily assembled lamp and reflector support that is essentially practical, attention is called to Fig. 14. Here a vertical telescop-

ing pipe is assembled with a "T" holding a cross pipe, such that two adjustments are provided, vertically and laterally, in addition to a swing. The fixture does not interfere with the operator in any way, and has proven entirely successful. Several modifications of this idea are met with, some using a three or four foot length of flexible steel armored tube instead of the pipe-support,

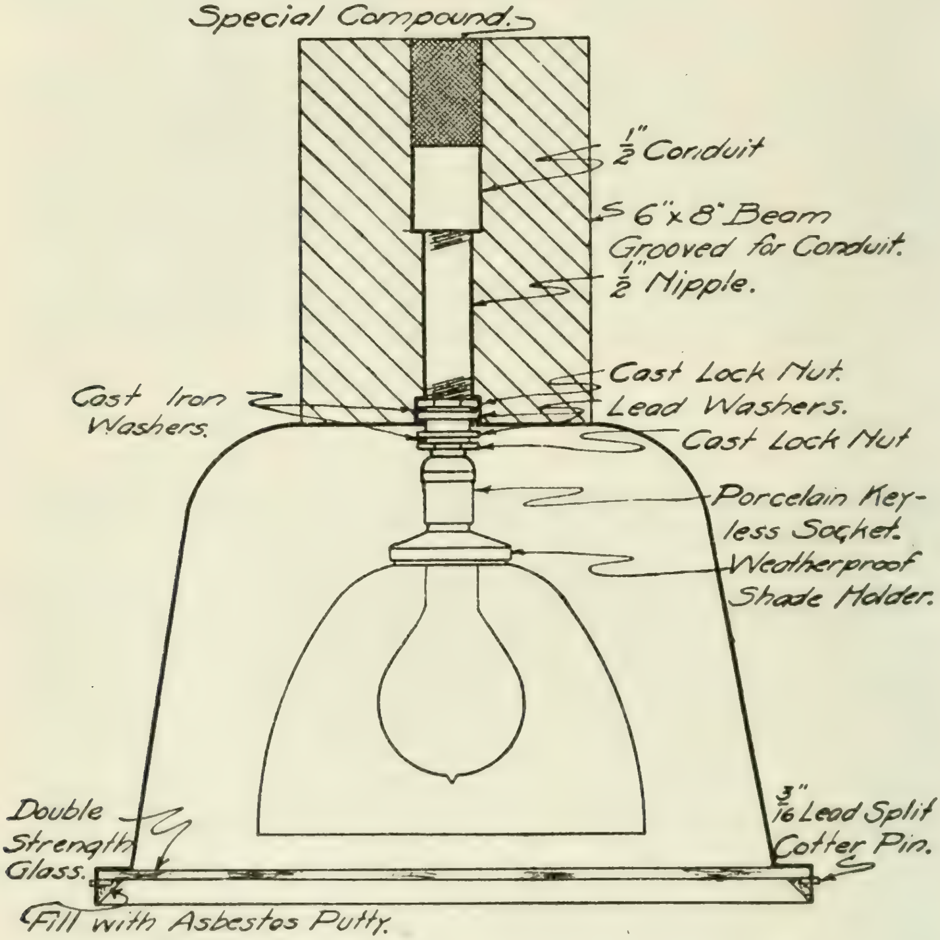

Fig. 11.—Acid-proof reflector and method of protecting conduit used in acid plants.

applicable where the electric service can be brought up near the work as on a small lathe. An important feature of all of these forms of unusual lighting is the placing of conduit beneath the floor to clear the working space of overhead wiring.

Horizontally directed light is frequently needed in mill operations, and one means of providing it is by an extension swinging

arm of conduit, pivoted on a "T" at the base and with a counter-balanced reflector and lamp at the other end. An operator using such a fixture is shown in Fig. 15. When not in use the counter-weight draws the reflector up to a position near the swinging arm.

Modifications of this form of local lighting sometimes takes the form shown in Fig. 16. Here the arm carries a counter-weighted drop cord at its outer end for the inspection of interior borings,

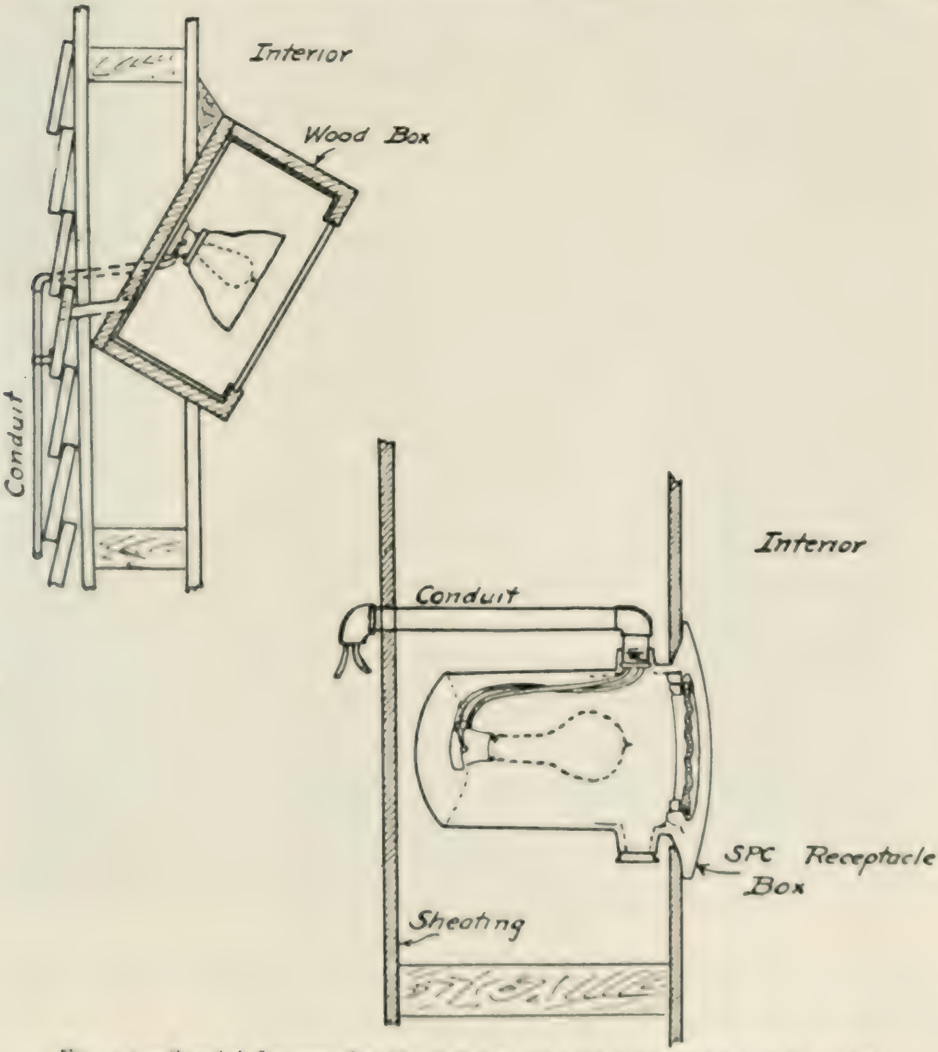

Fig. 12.—Special fixtures for the lighting of acid plants and powder mills.

and in addition a second drop with reflector, for the general machine illumination.

Permanent reflectors on conduit arms, installed as in Fig. 17, give good illumination of metal working benches, and eliminate all exposed wiring. Installation of this character function very much

better, and are really successful only if made solidly and symmetrically, mixing much mechanical ingenuity with illuminating engineering principles. Far too many adaptations of reflectors and lamps have been found within the writer's experience to lack such simple features as solid mechanical supports, or unbreakable adjustments, that would immeasurably increase their efficiency in mill lighting work. The lighting fixture must primarily be usable and unbreakable. In passing, attention may profitably be called to an unusual but very useful adjunct to mill lighting that appears in Fig. 17, *viz.*, the liberal use of white paint on the walls. Such a means of realizing the full value of natural as well as artificial lighting is out of the ordinary, — not because of its uniqueness but because of its rarity, and no opportunity to impress its real value upon the mind of the plant engineer should be neglected.

Examples could be illustrated ad infinitum that emphasize the possibilities of exercising ingenuity and common sense in the unusual applications of illuminants to industrial lighting. We have not mentioned, for instance, other illuminants than the mazda lamp; specially colored lights, that occasionally are serviceable, nor have we time to discuss such uses as of miniature lamps for local lighting of drill presses, stitching machines, or close detailed work. These examples will suggest others, and whatever may be the means of applying light to the betterment of industrial operators, the final thought is that with such a flexible illuminant as the mazda lamp, and with proper ingenuity and initiative in placing and equipping it for its particular duty, there is no lighting problem that the true illuminating engineer cannot solve.

DISCUSSION.

BASSETT JONES: I am not altogether in agreement with the idea of painting the walls of a factory white.

A man working in a factory or an office, with white walls and ceiling, has an enormous field of relatively high brightness, and a correspondingly large bright retinal image in his eye. Therefore, the average field brightness has to be very low if he is to work in any comfort at all, for glare is a function of the area and brightness of the retinal image. I prefer to paint the ceilings white

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Fig. 13.—The use of a wire guard to sustain broken glassware.

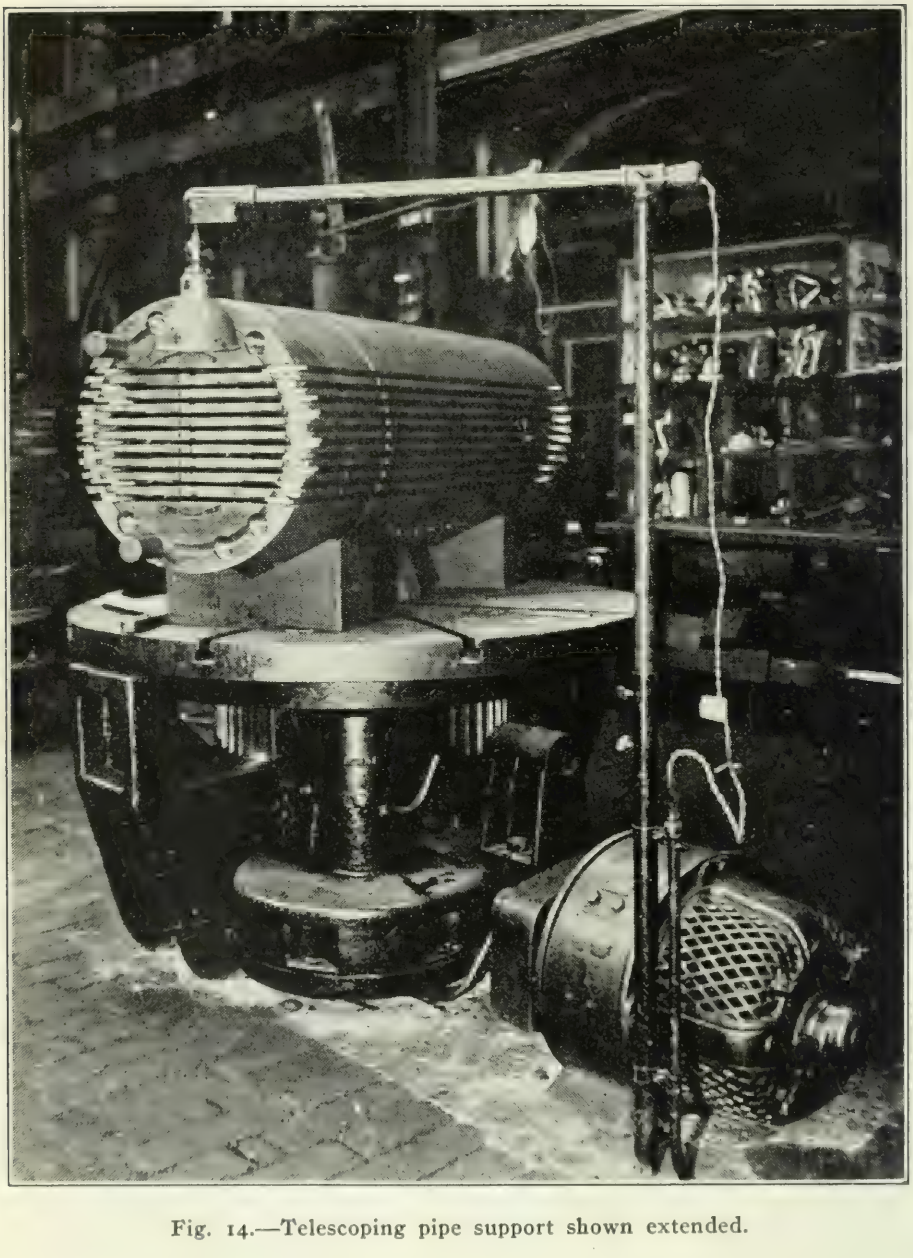

Fig. 14.—Telescoping pipe support shown extended.

5-58 13.

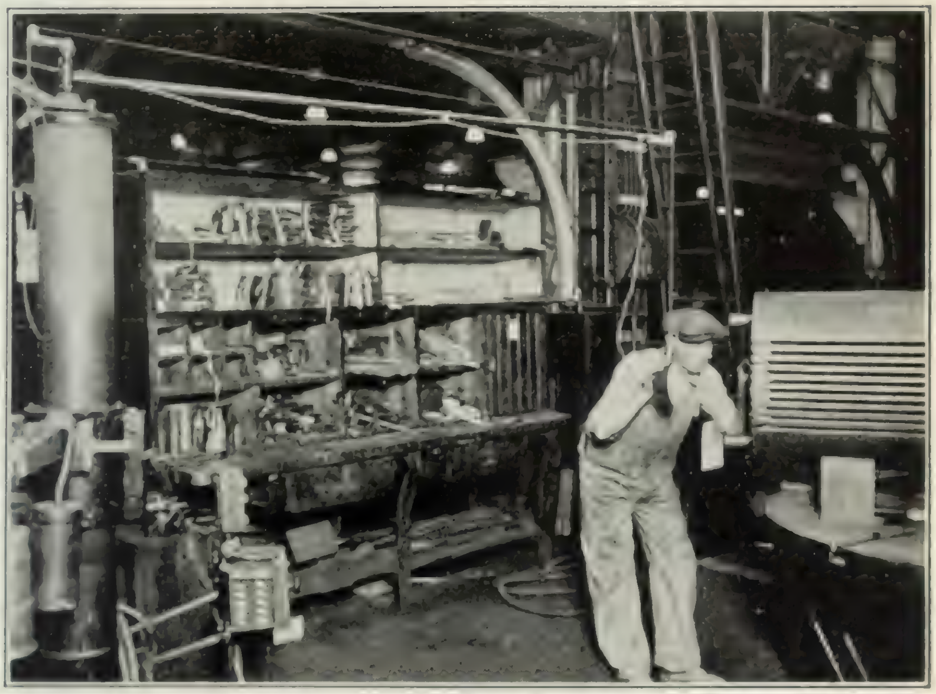

Fig. 15.—An adjustable local lamp for special inspections.

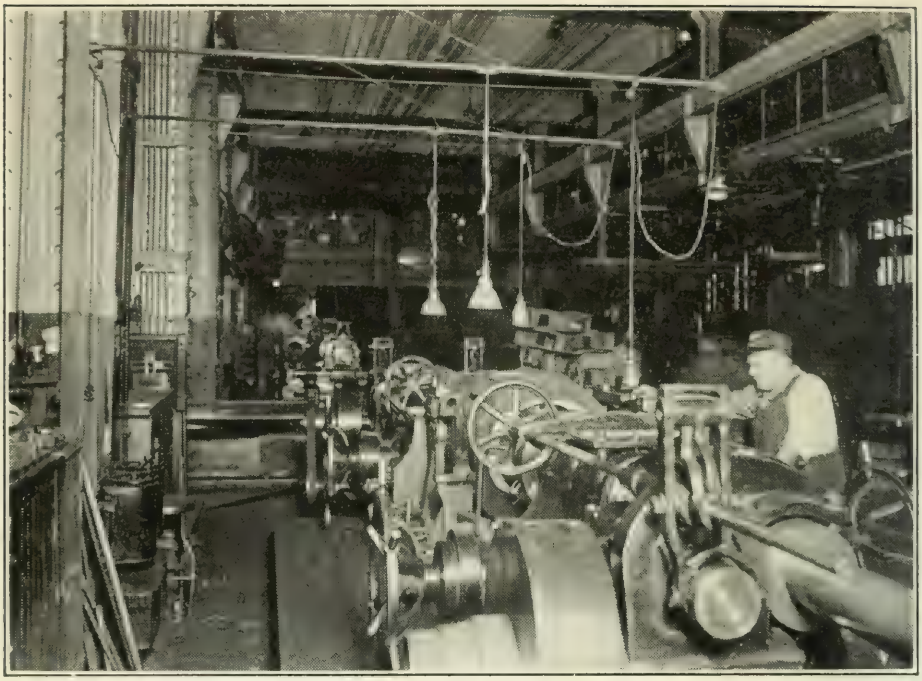

Fig. 16.—Swinging pipe arms for adjustable local lighting.

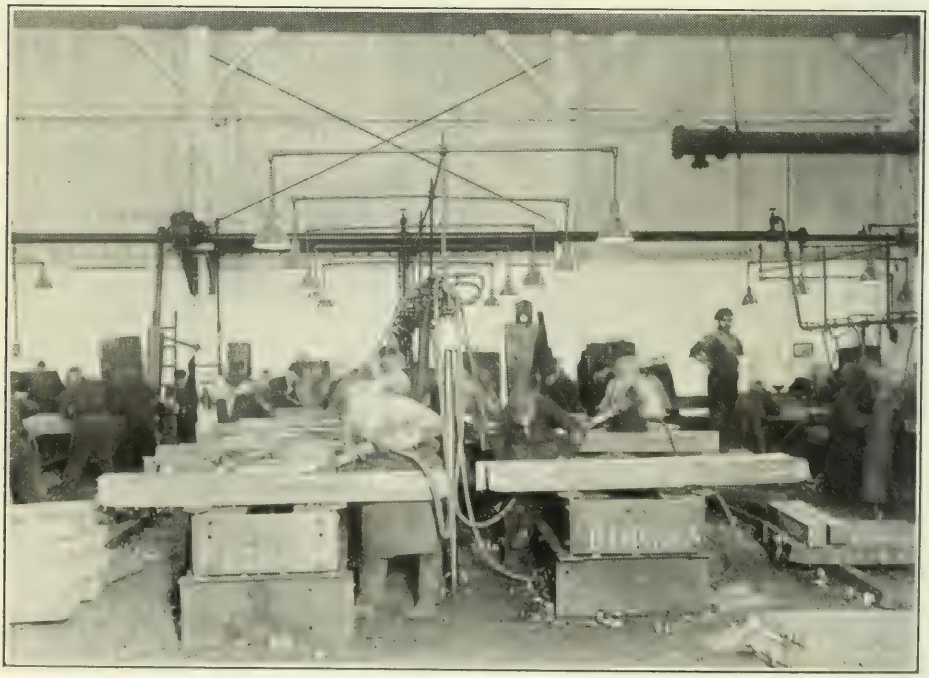

Fig. 17.—Simple and practical support of reflectors above metal chipping tables.

and the walls a soft light neutral tone—a gray yellowish-green to a line with the window heads.

The most extraordinary mistakes have been made in lighting of factories both by daylight and artificial light. We find the factory filled with window area, roughened so that the sky is brought out within 5 or 10 ft. of the worker's eye, and this naturally interferes with the worker's vision. Looking over a factory so lighted I noticed every man in the place had a visor or a green shield over his eye to help overcome the glare from the windows.

Window area costs almost twice as much as the equivalent area in wall structure and it costs much more to heat the factory with larger window area because it requires larger radiation. If the windows were omitted and artificial lighting were used 24 hours a day in the year, the cost of lighting would be about 50 per cent. of the window cost in first cost, maintenance, and heating accounts. I had such a case in an art museum and recommended that the architect cut out all the skylights, easily proving that artificial lighting used 24 hours a day giving an approximation to daylight, in color and distribution would cost just 50 per cent. of the cost entailed in the ventilating and heating required on account of the skylights, to say nothing of the extra costs of the skylights themselves.

Therefore, I say that in factories, windows as small as possible are desirable so glazed that the light is directed down the side aisles because, after all, in the usual three bay wide building, it is only in the side aisles where work is done.

J. R. Cravath: I would like to emphasize what has been said about the very bad effects of carrying the sky-line down to the lower window sill, by roughening the glass. The diffuse light from the glass is very trying because the eye is not accumstomed to having the sky brightness down at that level. When it comes to opposing painting the walls of the factory in light colors, that is another problem altogether. We all know that part of our troubles with glare come from extreme contrasts and the more we can reduce those contrasts by making the walls light, the less detrimental is the brightness we are getting from the window or the lighting units, whichever they may be.

BASSETT JONES: I am not opposing painting walls in light colors. Of course, they must be light, not bright. In my own practice I use a pale gray yellowish-green paint specially prepared. It has a reflection factor of 52 per cent. and a small ageing factor.

DAVIS TUCK: There has been a lot said recently about reflected or back glare from polished surfaces in factories. I think this should be taken with a grain of salt. Mr. Hibben said that it took a mechanic to be an illuminating engineer. Put yourself in the place of a mechanic. One of the operations you will have to perform is to scratch an intersecting hair line on a piece of polished metal and put a center punch mark at the point of intersection. Unless you have back glare this operation becomes very difficult. The necessity of back glare is also demonstrated when trying to read the small revisions on a metal scale or micrometer. There are many operations in machine shop work where back glare is essential.

O. L. JOHNSON: There is one thing I can see in Mr. Hibben's paper and that is that he has been able to take advantage of conditions that do not obtain in Chicago, where all wires must be conduit so it would be impossible for us to work such interesting stunts as he has described and shown.

E. A. ANDERSON: As suggested in Mr. Hibben's paper, very ingenious special local lighting arrangements may be wired out for particular machines requiring good light. Of course, if the general lighting system provides an illumination of from 10 to 15 foot-candles instead of only a low illumination of 2 or 3 foot-candles, the special lighting for these operations is very often rendered totally unnecessary. It is undoubtedly true that in some locations where there are wide areas with little detail work being done, it is more economical to have the general system of low intensity with special lighting for the few spots which require it. On the other hand it is surprising in how many instances a high level of general lighting represents true economy in cost. Especially is this true if in calculating the expense of the lighting the engineering and special installation work as well as the expense of rewiring when machinery is shifted is included in the total.

For those locations where special local lighting equipment is necessary there are certainly great possibilities for improving the mechanical construction and lighting effect over the makeshifts seen in so many otherwise modern plants.

JULIUS DANIELS: In submitting lighting suggestions for factories, experience has shown that a familiarity with the wiring code is necessary. Consideration should be given to the wiring and mechanical details of the installation as well as the spacing of the lighting units. By this means the confidence of the contractor can be obtained, thereby securing an important ally for the cause of good lighting. The lighting industry would be greatly benefited if such attention to details as is shown by Mr. Hibben's paper were not "out of the ordinary applications of industrial lighting," but came within the province of every illuminating engineer when designing industrial lighting.

S. G. HIBBEN: There is nothing much further to be said except in regard to white paint. Considerations of the use of light colored paints, in factories, can be based not only on the reduction of contrast, but on this other fact that the walls are usually irregular, broken by columns, window spaces and what not, so that the actual exposed light-giving area of painted walls in the directions where workmen look is not very great.

I am much in favor of reducing the large area of bright windows, placed low in the field of vision, and I think the manufacturers of sheet glass and factory glass ought to be induced to investigate this problem along with the illuminating engineers. This is not a problem of less window area, but of its placement, the use of refracting prisms, and the use of curtains.

Open wiring versus conduit offers a large field for discussion and perhaps it is not within our province to discuss it here. However, in a great many of our mill lighting operations in the Middle West, we cannot afford conduit wiring. Notwithstanding its undoubted advantages the mill owner will not put it in. Therefore the illuminating engineer must know what is permissible, and how to fit the wiring codes to local needs.

When we read in the rules that circuits shall be limited to 660 watts, and yet we require 750- or 1,000-watt lamps, we should

know how to make the installation comply. We must know what is feasible and what the underwriters will pass. That constitutes usable illuminating engineering.

I favor high values of overhead lighting, but places like a large blooming or rail mill, where work is done on long roll tables, could not be lighted to 10 or 15 foot-candles throughout, and such cases suggest the reason for utilizing special local lighting.

THE LIGHTING OF SHOE FACTORIES.*

BY A. L. POWELL AND J. H. KURLANDER.

The exploitation of the field of industrial lighting has brought about many marked advances of new methods over old. The past few years have witnessed such great changes in factory-lighting that daylight conditions are simulated and in the case of old factories, where natural illumination was especially poor, even exceeded.

One of the primary causes of this departure from old methods of illumination was the speeding up of production made necessary by the war and which is still essential during the reconstruction period.

Many factors have contributed to these improvements in industrial lighting, some of which are the new types of lamps, increased efficiency of reflectors and new methods of employing these appliances to secure the maximum utilization of light. The three causes named are closely inter-related and each must of necessity, contribute its share if satisfactory results are to be obtained.

New systems of lighting have been practically forced into existence by the advent of more powerful lamps and their appurtenances. The systems referred to are what are known as general and localized general systems of illumination. Their respective merits are so well known to the illuminating profession, that no lengthy description of them is necessary here. These two systems are replacing or already have replaced the local lighting so prevalent in the days of the old carbon lamp and the earlier forms of mazda B lamp.

The change-over from local lighting to general lighting has brought out many peculiar problems which have shown that local lighting cannot be altogether abolished. One class of industry which clings tenaciously to this means of illumination is that of shoe manufacturing. Considerable time has been expended on investigations for determining the possibility of introducing general and localized general lighting in shoe factories and many processes are found to be well adapted to this form of lighting with its natural advantages.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

It may be well before discussing any particular type of installation for shoe factories to describe briefly some of the conditions now existing in them and to enumerate the causes which have effected these conditions. The successful lighting of the great majority of shoe factories presents a problem which calls for the utmost in thought and care. Two factors contribute directly to this state of affairs. One is the exacting nature of the art of shoe making, together with the complexity of the machines which perform this work, the other is the arrangement of the machines in the factories themselves, the machines being lined up along the windows on each side of the building in order to secure the maximum amount of daylight on the work. This is a condition which has grown up with the industry before the need of artificial illumination was felt.

The Mayflower on her second trip, brought over one Thomas Beard, a shoemaker, the first in America. Later several others came from England bringing their own supply of hides with them and the art of shoemaking became firmly established in the Colonial states.

Shoemaking at this time and up until 1845, when the first machine came into use, was purely a matter of hand operation. A boy who wished to learn the art of shoemaking served an apprenticeship of seven years during which he learned all of the details of the trade including the making of turned, sewed, pegged and screwed shoes. He usually sat by a window and worked, pegging, stitching, cutting and hammering until the shoe was completed. This method obtained until well up to the middle of the nineteenth century when journeymen became aware of the fact that they could do better by having individuals perform particular operations while they directed them. This was the beginning of the factory system, the factories at that time usually being small shacks about ten feet square some of which are still standing in the back yards of Lynn. Artificial illumination was rarely if ever used, the operator ceasing to work when daylight failed him. With the advent of machines from time to time, the old hand method of making shoes gradually died out and the factory system such as is known to-day had its inception. As the various machines came into use they were quite naturally placed where the best illumination could be had, namely, next to the windows.

Now we see machine after machine lined up along the windows on either side of the building.

With the growth of the shoe industry larger factories came into being and to-day we see factories employing from a few hundred to several thousand workers turning out from a thousand to tens of thousands pairs of shoes per day. Along with these larger factories came the need of artificial illumination, as not all of the workers could be placed near the windows. Again, the industry could not be so tied down to this means of illumination as to cease all work when it failed. Oil lamps, open flame gas burners and later mantle burners were used to a considerable extent but these means of illumination are gradually being superseded by the incandescent lamp.

As a result of a number of contributing causes, shoe factories as a class are not well lighted according to our present day standards. In attempting to install proper lighting, one encounters certain objections on the part of the operators for from the time shoe making was in its infancy, shoemakers have been of the opinion that there is no substitute for natural illumination. In a number of cases as indicated in some of the accompanying illustrations, the attempt has been made to provide general lighting and systems have apparently been installed with no appreciation of the various factors involved, in fact, observation of many of these shows a pure hit and miss process of installation. Shadow effects and the relative location of light sources and machinery have been given no consideration whatever. It is quite natural, therefore, that the impression has been created in the minds of some managers that shoe-making cannot be well lighted. The writers frequently were told "we have tried overhead lighting with large units and it is no good for our work." Upon looking into the matter in most of these cases, it could readily be seen that the kind of general lighting they had been trying would be unsatisfactory.

The claim is also made without an appreciation of the benefits which accrue from high intensity illumination that it is not really needed in the shoe factory for the only demand for artificial light is to supplement daylight. This is true to a slight degree, for the nature of the trade is such that the operator does not work either a full day or the entire week. He receives a certain amount of

work and if he is fairly rapid, he can finish before the allotted time and his work proceeds to the next operation. This condition prevails quite extensively throughout the industry and as a result full time and night work is not as prevalent as it is in other plants. Local lighting is in general the practice and each operator under this system controls his own lamp. The superintendent or manager is inclined to believe that there is therefore very little waste of light. This method of illumination, although fighting bitterly for existence, is slowly giving way to general or localized general illumination with its natural advantages.

The present placement of machines along the windows, however, does not lend itself to the use of a purely general system. The operators are accustomed to work by means of light coming through the windows and due consideration must therefore be given the directional effect of the overhead lighting. It is not so much a question as to whether the various shoe making operations can be lighted without local lamps, as it is of successfully adapting general lighting to the present layout of the shop.

The question of artificial illumination has been given little or no consideration by the architect in designing the buildings used for this purpose, a great majority of them being built prior to the widespread use of modern day illuminants. With the latest types of high efficiency light sources and effective reflector equipment, daylight effects can be readily secured and there is no longer any need of adhering to the system of arranging the machines along the windows. It is really advisable in any industrial plant to place machines so that artificial lighting can replace natural lighting without a diminution of output. Such a change cannot be made over night, but as new factories are built and old ones altered, the lighting question and machine arrangement should receive careful consideration.

It is true that in the shoe factory the need of good diffusion has long been recognized and as a result walls and ceilings are either white-washed or painted white. Light colored shades are generally provided for the windows which assist in reflecting the light from such lamps as are in use. There is still plenty of room for improvement in the matter of painting, because in many instances after the first coat of white-wash has been applied to the wood ceiling or the brick walls, further attention is apparently

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Fig. 1.—Night view of a leather storage room lighted by 200-watt mazda C lamps in enameled steel dome reflectors. These are placed on 10 ft. centers approximately 10 ft. above the floor. The high intensity of illumination is made necessary by the variation in color of the leather. In selecting material from stock, it is essential to use considerable discrimination. The daylight mazda lamp finds application in this part of the plant.

Fig. 2.—Sole leather cutting machines or beam dinkers lighted by general illumination. It is essential that the light in this room be well diffused, in order that it may penetrate beneath the overhanging parts. The white surroundings assist materially in producing the desired effect. In this particular installation two 100-watt dome reflector units are used in each 10 by 15 ft. bay.

Fig. 3.—Hand cutting boards illuminated to a high intensity by general lighting. Since patterns must be accurately followed and costly material is handled, good lighting is an essential element in eliminating waste or spoilage.

Fig. 4.—Typical lighting conditions encountered in the stitching room of the shoe factory. Local lights above the benches are the only source of illumination. The room is dingy and unpleasant for the workers. Reflected glare is a serious element. The installation is most untidy without any degree of uniformity. Shadows are dense and shoe racks at the left are particularly conspicuous through their lack of lighting.

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Fig. 5.—It is certainly much more pleasant to work in this up-to-date stitching room. A moderate intensity (4 foot-candles) of general illumination is supplied by 300-watt semi-enclosing units close to the ceiling, one in each 20 ft. bay. These are supplemented by local lights for each machine. A carefully designed adjustable arm is supplied, rather than the unsightly drop cord and the 25-watt mazda lamps are provided with a small reflector especially designed for this service. Such units properly placed provide a high intensity at the needle point and can be located to avoid glare reflections.

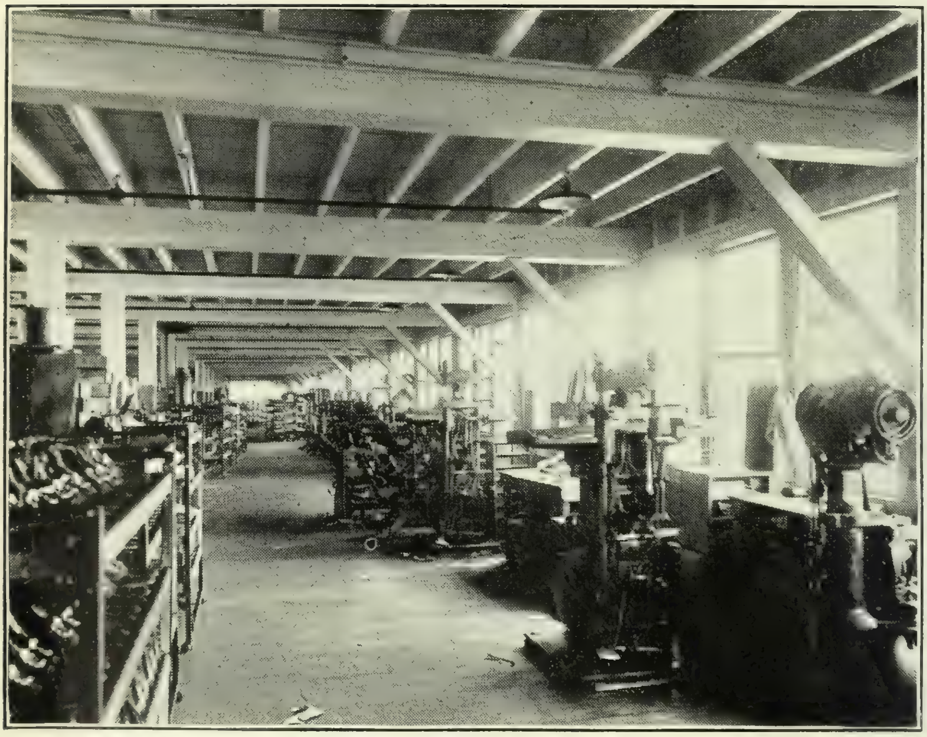


Fig. 6.—Daylight view in a making room equipped with the most modern types of machines with individual electric drive. The excellent daylight illumination is worthy of comment, practically the entire wall space being devoted to windows. Further examination of this point, however, reveals one of the reasons why the shoe manufacturer believes artificial lighting to be impractical. A maximum amount of daylight has been supplied and yet the sole lighting equipment for each bay 10 by 15 ft. is one 75-watt mazda C lamp hung 10 ft. above the floor. To add to the ineffectiveness of the lighting, the reflector employed was not designed for this size of lamp, the clear bulbs project far below the edge of the reflector introducing a high degree of glare and a very poor utilization of light.

deemed unnecessary. The white-wash flakes off or becomes very dirty. Dull white enamel would be far more permanent. The class of buildings under consideration is characterized by low ceiling heights ranging from ten to fifteen feet with an average of twelve feet. This precludes the use of large overhead units as light is required at any point from several directions. Too large lamps have often been indiscretely used in trial installations and provide another excuse for those in the shoe industry believing that local lighting is the only kind applicable to their problem. The central portion of most rooms are used as storage spaces for shoe racks which extend four or five feet above the floor. This also reacts against purely general lighting in cutting off light from surrounding lamps. It is obvious that until the construction of the buildings and the arrangement of the machinery are altered, the ordinary methods of symmetrical lighting, satisfactory in most industrial plants, are not generally suited to the shoe factory. In other words, one cannot take a plan and spot in lighting outlets in a regular fashion, but must study the relative arrangement of machines.

Remarkable improvements can be made particularly in those shops having no other than local illumination, by the installation of a modified, localized general system.

The attempt is made in this paper to analyze the lighting requirements of the individual machines and specify what arrangement of illuminating apparatus best meets these needs. As far as possible, our aim is to make suggestions which can be applied to existing conditions. It is unnecessary to go into detail as to the benefits resultant from good general illumination. The following points, however, come to mind as one analyzes the effects of local lighting.

The individual lamps represent a high cost of installation and constitute a large maintenance charge. They produce a small spot of bright illumination directly beneath the unit in contrast to the much darker surroundings which is not a good condition for the eye. Local lamp installations, unless very carefully designed, are likely to constitute an electrical hazard and become most unsightly.

There is a tendency for the operators to fuss and fool with the lamps, trying out new positions in order to secure better light. This means the loss of many moments, and as most of this class of work is piece work, the time so wasted represents an actual loss to both employer and employee. As long as lamps are placed within the reach of the workers, it is only human for them to keep altering their position so as to try out new effects.

There is another element in this question which may well be given consideration. The present labor situation is such that manufacturers must humor the whims of their employees to a greater or less extent, and as a result, when once accustomed to working under such conditions, they object strenuously to any changes, no matter how poor or detrimental the present conditions may be, both to themselves and to their employer. This is especially so in shoe factories, and it is no uncommon incident to have the men in the cutting-room and those performing operations particularly exacting in nature stop work at four o'clock on a winter afternoon as daylight begins to fail them, complaining that it is too dark for them to perform their work in a satisfactory manner. A well designed system of illumination would take care of such matters as this.

The following recommendations must be made somewhat elastic, as it is impossible to lay down hard and fast rules governing the lighting of all factories. This may be illustrated by the fact that in large companies, an entire room may be devoted to a single operation which lends itself admirably to the installation of a general or a localized general system, while in smaller factories, a multiplicity of operations is performed in one room, due to lack of floor space. In such cases, it is hard to design a system which will take care of each operation. Lamps may be placed with particular regard to one class of work which would be altogether unsuitable to other processes twenty feet away. Where this occurs, and it occurs very frequently, it is purely a matter of good judgment and a thorough knowledge of what is required.

As pointed out, in quite a number of factories, well-meaning attempts have been made to install better lighting systems, but the equipment has been such as to favor the results very little.

Usually, the electrician in charge of the work has made no systematic investigation and merely tries out one installation after

another trusting to snap judgment and luck to secure the desired effects. It is not uncommon to see two or three kinds of reflectors, suspended at various heights, containing 75, 100 or 150 watt lamps in the same room.

While the results obtained are far from being desirable, still these are pleasing indications that the need of good lighting is really felt, and that the manufacturers, as a rule are trying to do their best in this respect.

DIVISIONS OF SUBJECT.

Leather Shoe Factories.—The making of a shoe is a rather complicated process and the factory is usually divided into five departments, each department occupying a separate floor. The order customarily followed in arranging these is as given below:

Basement—Sole Leather Department.
First Floor—Packing and Shipping Department.
Second Floor—Finishing Department.
Third Floor—Making Department or Gang Room.
Fourth Floor—Upper Leather Department.

In large factories the individual departments may be subdivided into smaller rooms bearing the name of the particular operation performed in it. Thus, the upper leather department is usually separated into the stitching, cutting, skiving, etc., rooms. These may or may not be partitioned off from each other.

Rubber Shoe Factories.—While rubber shoes serve a purpose similar in certain respects to that of leather shoes in that they protect the feet of the wearer from rain, snow and moisture, the processes of manufacture, while having a few points in common with the manufacture of leather shoes, are entirely different in others. After the rubber is prepared, it is purely a matter of hand operation until the shoes are completed. The crude rubber is first ground and washed, run through compounding machines, rolled, calendared, gummed onto cloth and finally inspected. It is then ready for the cutting room where wonderfully skilled workers rapidly cut out the patterns which are stamped on the rubber. Then instead of a progressive order of manufacture such as found in leather shoe factories, the individual parts which go to make up a complete rubber shoe, are given to a single operator, who performs all the work necessary to turn out a completed shoe.

The shoes are held together by natural adhesive power and also by the application of cement. No nails of any sort are used. After the soles are dinked out on the dinking machine, the parts of the shoe, such as the lining, sole, vamp, base, counter, tip, heel, etc., are built upon the last until the shoe is completed.

There are only a few machine operations in the manufacture of rubber shoes. This simplifies the matter to a great extent, but in the preparation of crude rubber, the grinders, rollers, washers and dryers together with the calenders and compounding machines offer difficulties to proper lighting.

General Lighting Requirements.—The processes in the shoe factory can be grouped into three general divisions:

(*a*) Work similar to that carried on in the ordinary industrial plants, involving no machines with overhanging parts and having demands for low, medium or high intensity, depending on the degree of fineness of the work. The standard type of general illumination meets these conditions.

(*b*) Work on machines with overhanging parts are so grouped as to demand particular directions of light at the working points. Most of this work is relatively minute and demands a high intensity. The localized general system applies here.

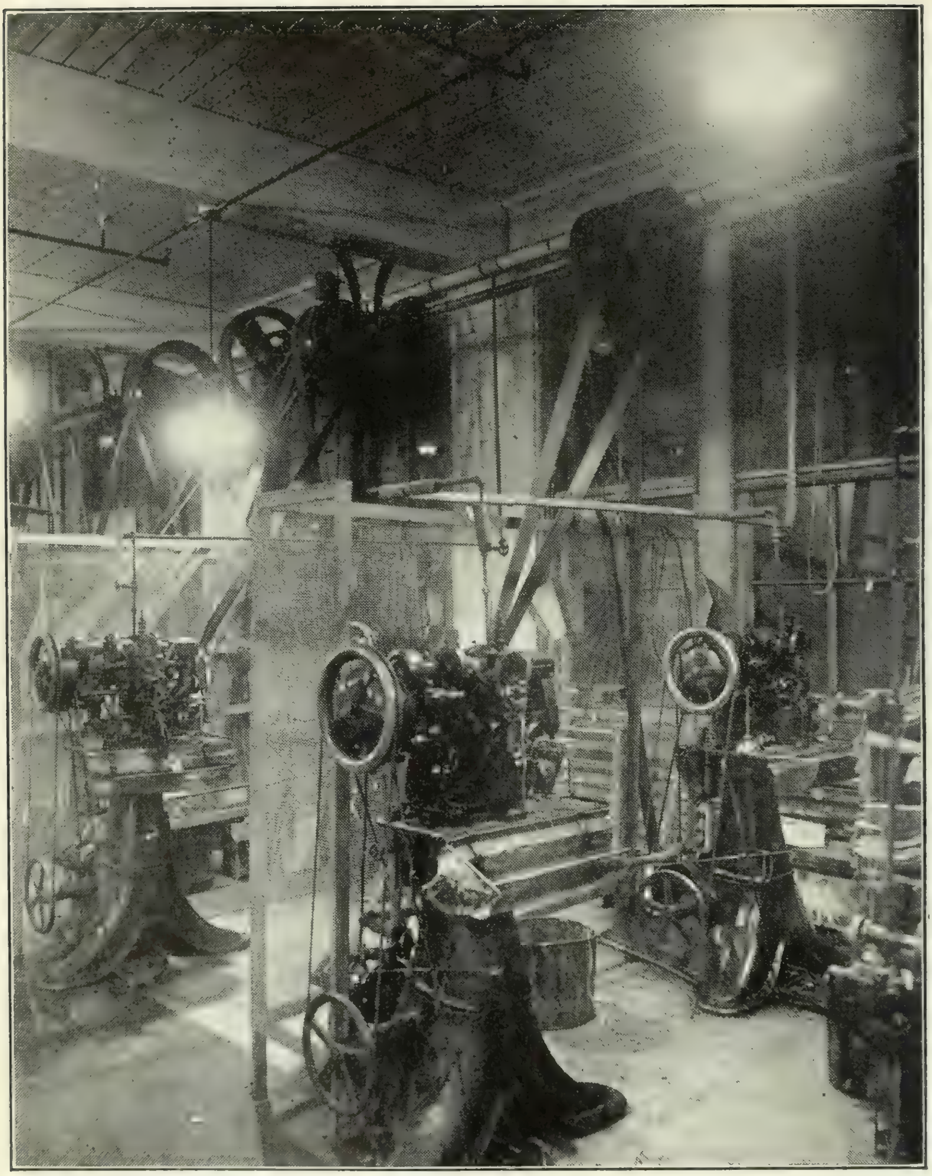
(*c*) Certain classes of work, such as stitching on dark material require an unusually high intensity which in many cases could not be economically provided by overhead units. This requires a combination of local and general lighting.

Sole Leather Department.—This department shown in Fig. 13 deals with preparation of soles, insoles, counters, toe boxes and heels. The work in comparison with the other operations in this factory is fairly rough and the lighting needs can be taken care of entirely by overhead lighting.

There is one type of machine, however, contained in this department which offers some difficulty unless the units are arranged with particular regard to it. This is known as a beam dinker which is used to stamp out the soles and insoles. It consists of a heavy cast iron frame work and a large beam which has a vertical motion and exerts a pressure on a die which in turn rests on the leather and a large block of wood placed there for the purpose of protecting the cutting edges of the die.

610'

Fig. 7.—Night view of a making room which is provided with reasonably good illumination. One 100-watt mazda C lamp in an enameled steel dome reflector is placed in the center of each 15 ft. bay. The view, however, illustrates one of the phases discussed in the text, *i. e.*, improper placement of units. With the present position of light sources each operator casts a shadow on the working point. If common sense had been employed and the localized general system used with the row of outlets shifted so that the lamps were approximately 4 ft. from the wall, this difficulty would have been overcome and the overhead lighting system would not have been subject to the criticism on the part of the operators.



Fg. 8.—Close-up night view of Goodyear rapid sole stitching machine properly illuminated by the localized general system. 75-watt mazda C lamps in the proper size enameled steel dome reflectors are correctly located in reference to the machinery. It will be seen that outlets are located much nearer the walls than is customary practice. The excellent light on the working point is worthy of comment and the operator will not cast shadows on the work. The safeguarding of belting and moving parts speaks well for the progressiveness of this manufacturer.

610²

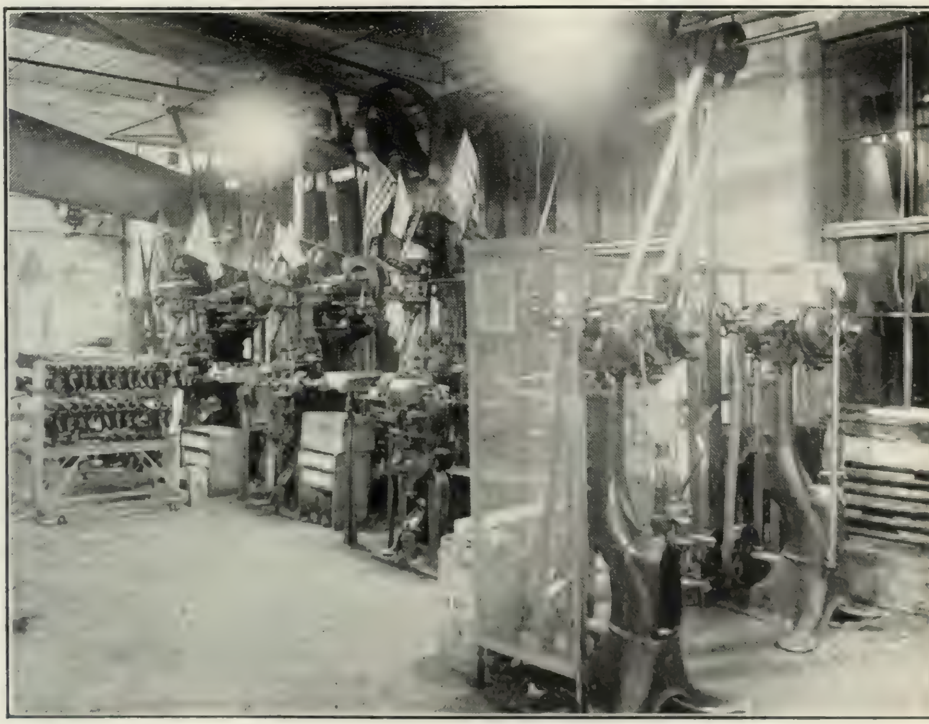


Fig. 9.—McKay automatic heel loading and attaching machines as they appear by night under the localized general lighting system. Such a layout as this permits the work to be carried on effectively and provides a pleasing room. One of the indirect effects of good general lighting is the promotion of neatness and sanitation.

Fig. 10.—General illumination of a treeing room showing the possibilities of this system of lighting. 100-watt mazda C lamps in dome type industrial reflectors are hung 9 ft. above the floor on centers 8 by 12 ft. and spaced so as to provide approximately 1 watt per square foot of floor area. This is entirely adequate for the white shoes being treed in this particular section. The white shades are drawn after sundown and assist materially in diffusing and reflecting the light.

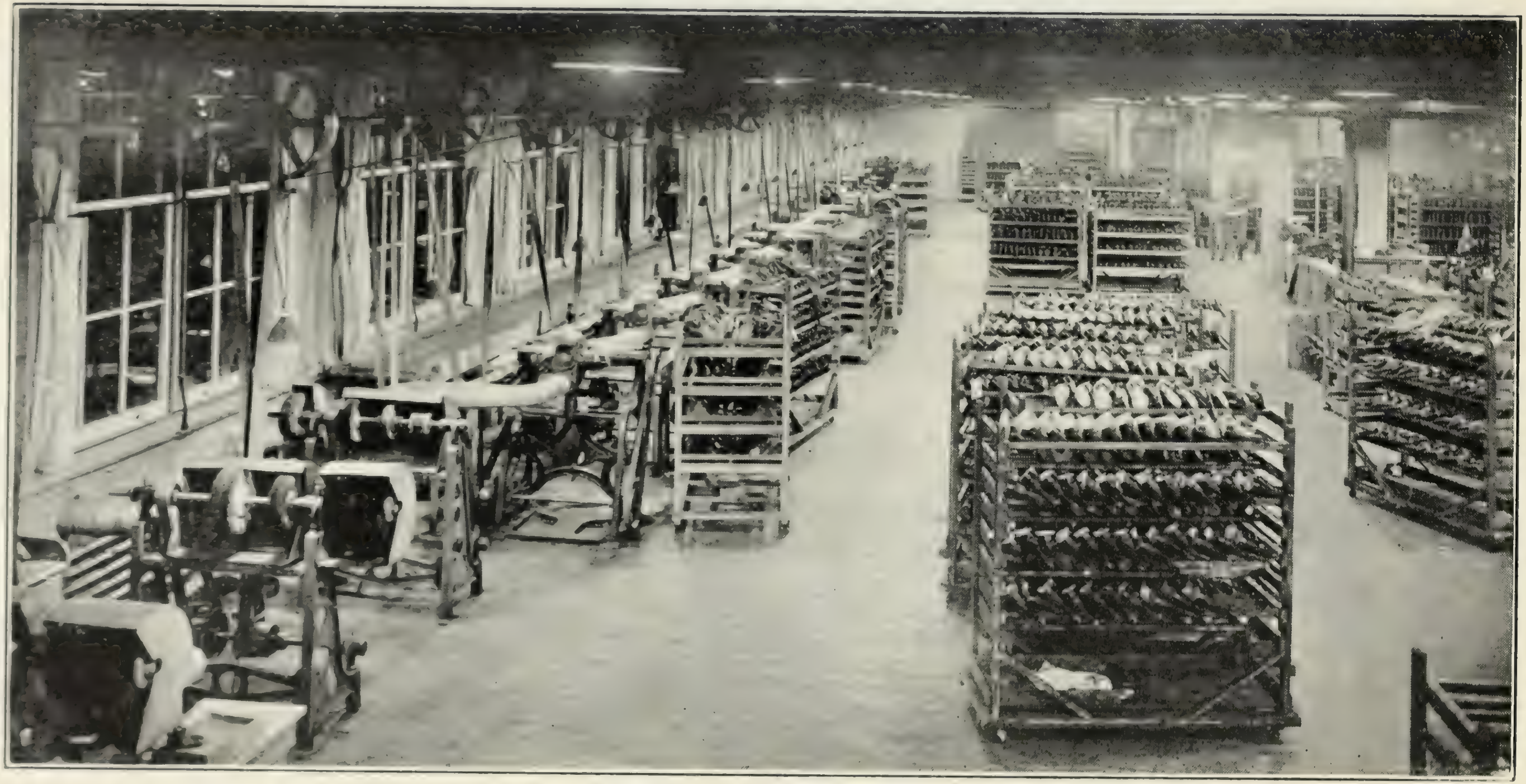


Fig. 11.—A combination of a moderate intensity of general illumination and properly designed and installed local lighting in a bottoming room. The tidiness is particularly commendable and the shoe racks are well illuminated.

610 3.

Fig. 12.—Night view of box making machines illuminated by the general system. One 300-watt mazda C lamp in a semi-enclosing fixture is placed close to the ceiling in each 20 ft. bay. A high degree of diffusion is secured and the intensity provided (4 foot-candles) is entirely adequate for this work which does not require close visual application. The sliding curtains of light colored material are an excellent feature of the equipment and proper manipulation of these enables the daylighting to be carefully controlled. The painting of the ceiling and the upper part of the columns flat white and the lower part of the side walls and columns dark tones is excellent practice.

SHOE FACTORY OPERATIONS GROUPED AS TO LIGHTING SYSTEM.

LEATHER.

General		Localized General		Local and General	
Leather storage	3 foot-candles	Dinking	6 foot-candles	Perforating	10 foot-candles
Cutting	10 "	Last racks	3 "	Stitching	20 "
Skiving and splitting	6–8 "	Lasting	3 "	Button holing	10 "
Staying	6 "	Pulling over	8 "	Eyeletting	10 "
Sole laying	6 "	Trimming	8 "		
Leveling	6 "	Welting	8 "		
Nailing	8 "	Rough rounding	8 "		
Treeing	12 "	Sole stitching	8 "		
Heel scouring	6 "	Channeling	8 "		
Burnishing	6 "	Heel breasting	8 "		
Spraying	6 "	Edge trimming	8 "		
Bench work	4–8 "	Edge setting	8 "		
Box making	4 "				

RUBBER.

General		Localized General		Local and General	
Washing	3 foot-candles	Calendaring	6 foot-candles	Sole rolling	10 foot-candles
Milling	6 "				
Compounding	4 "				
Cutting	10 "				
Making	12 "				

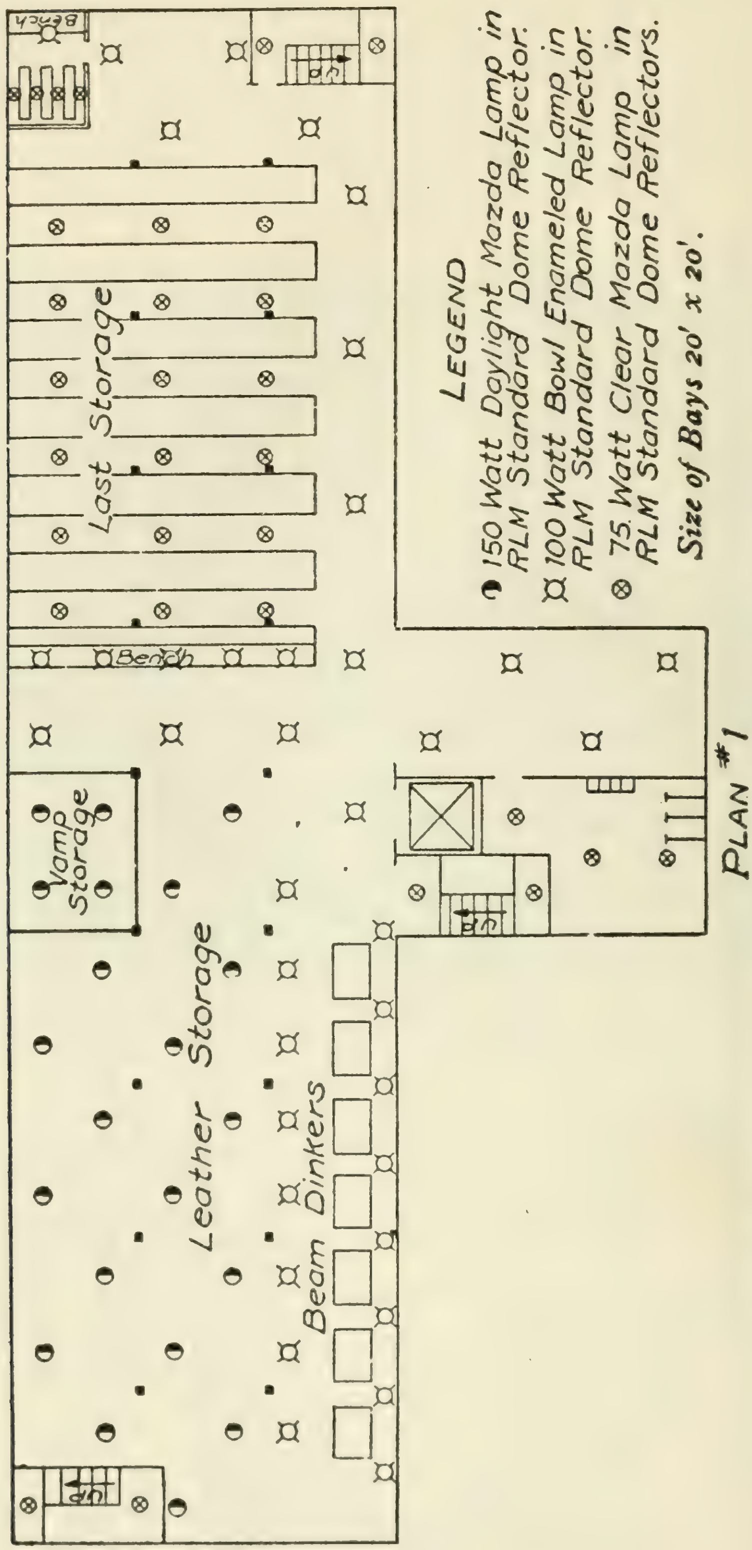


Fig. 13.—Model shoe factory, basement floor plan, storage and sole leather department.

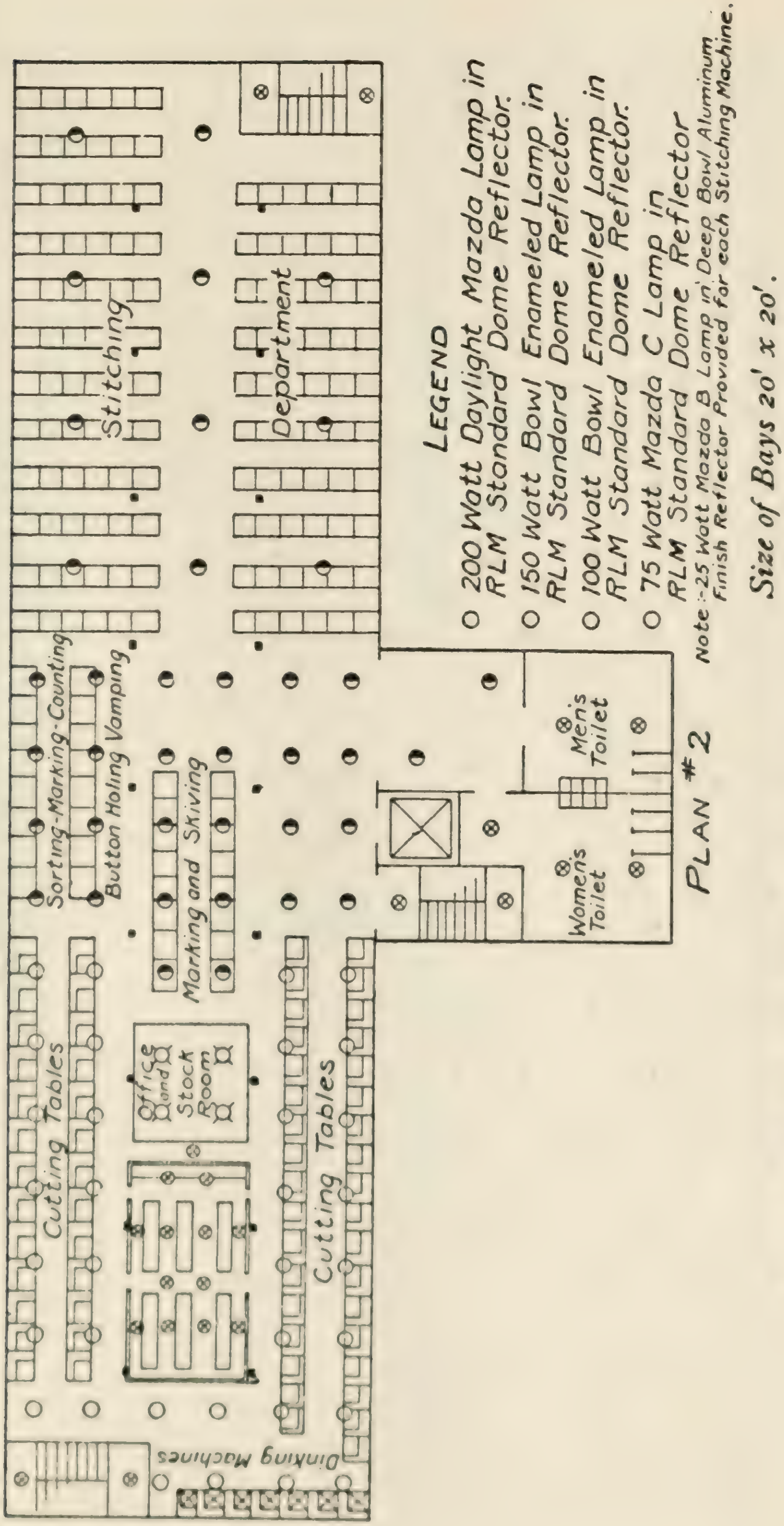


Fig. 14.—Model shoe factory, fourth floor plan, upper leather department, cutting and stitching.

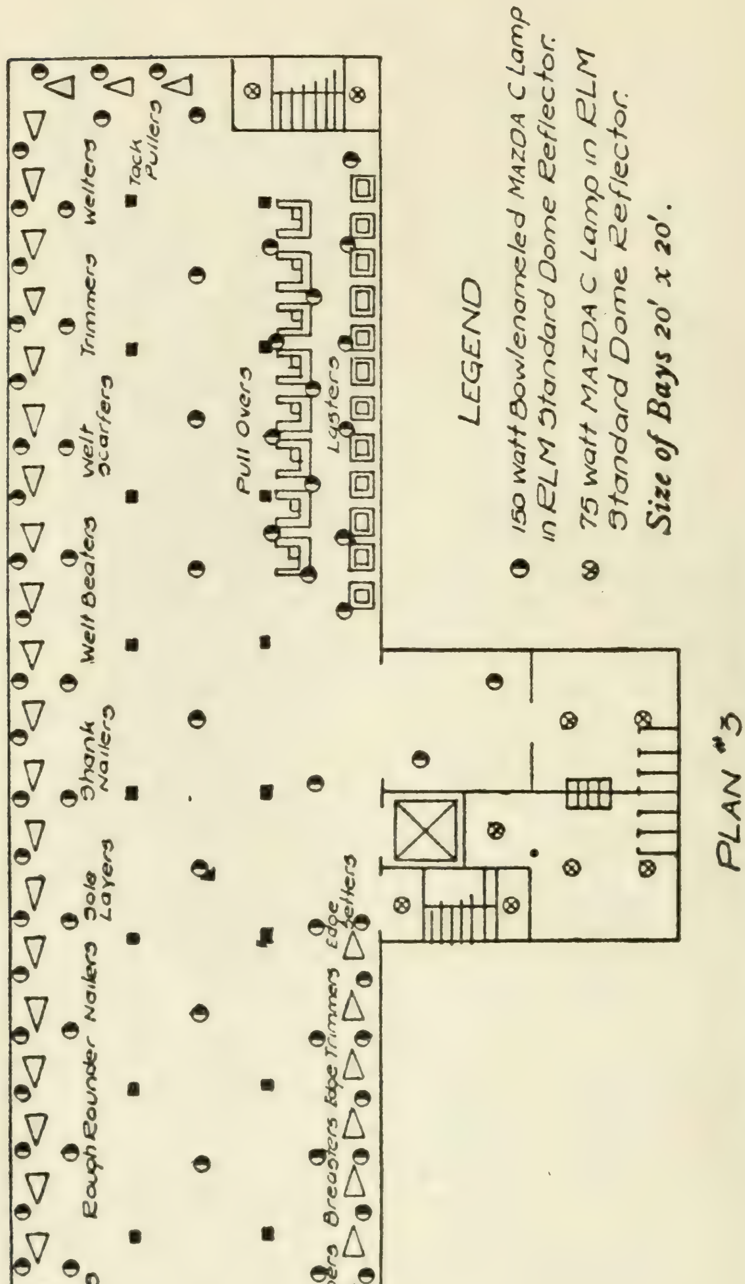


Fig. 15.—Model shoe factory, third floor plan, making department.

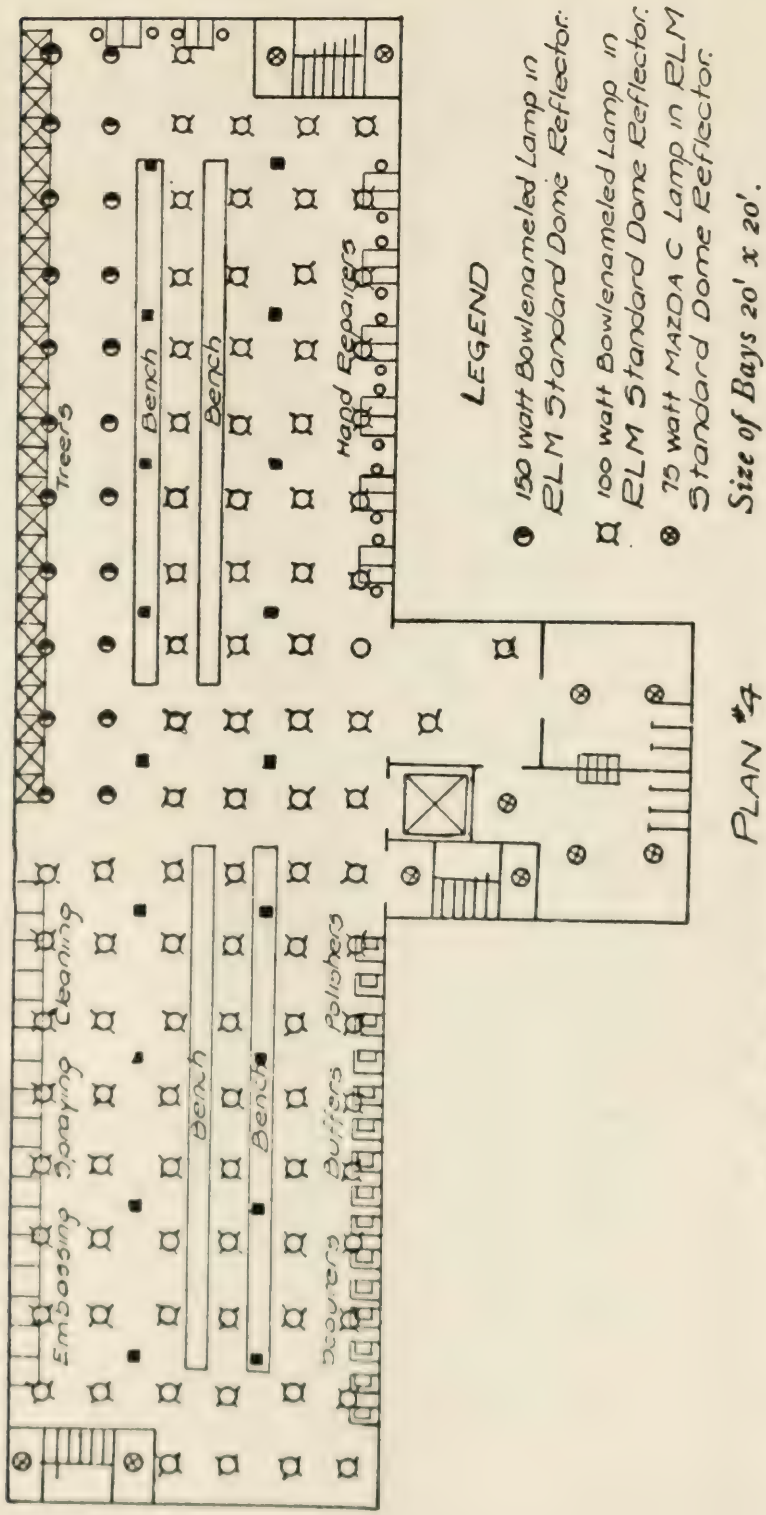


Fig. 16.—Model shoe factory, second floor plan, finishing department.

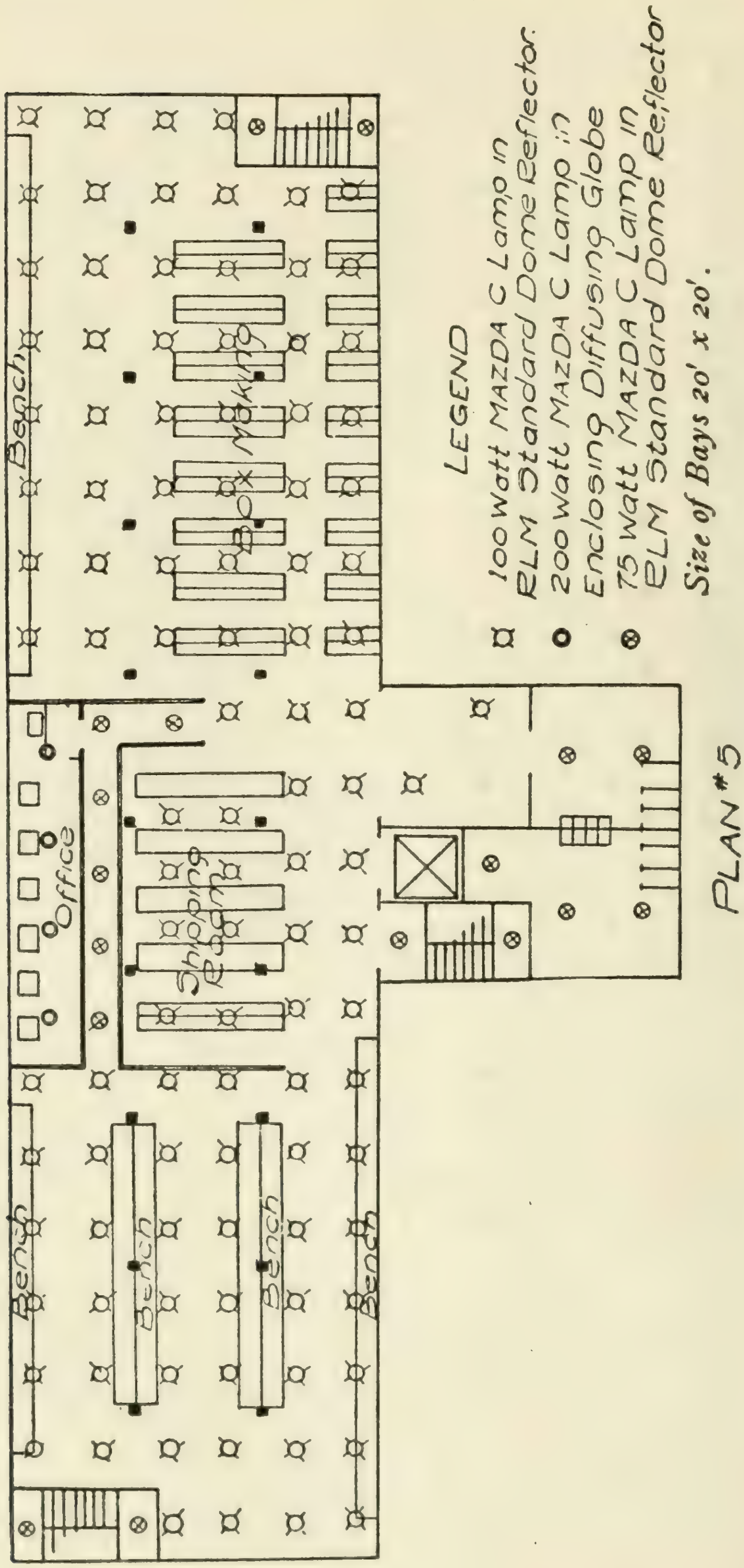


Fig. 17.—Model shoe factory, first floor plan, packing and shipping department.

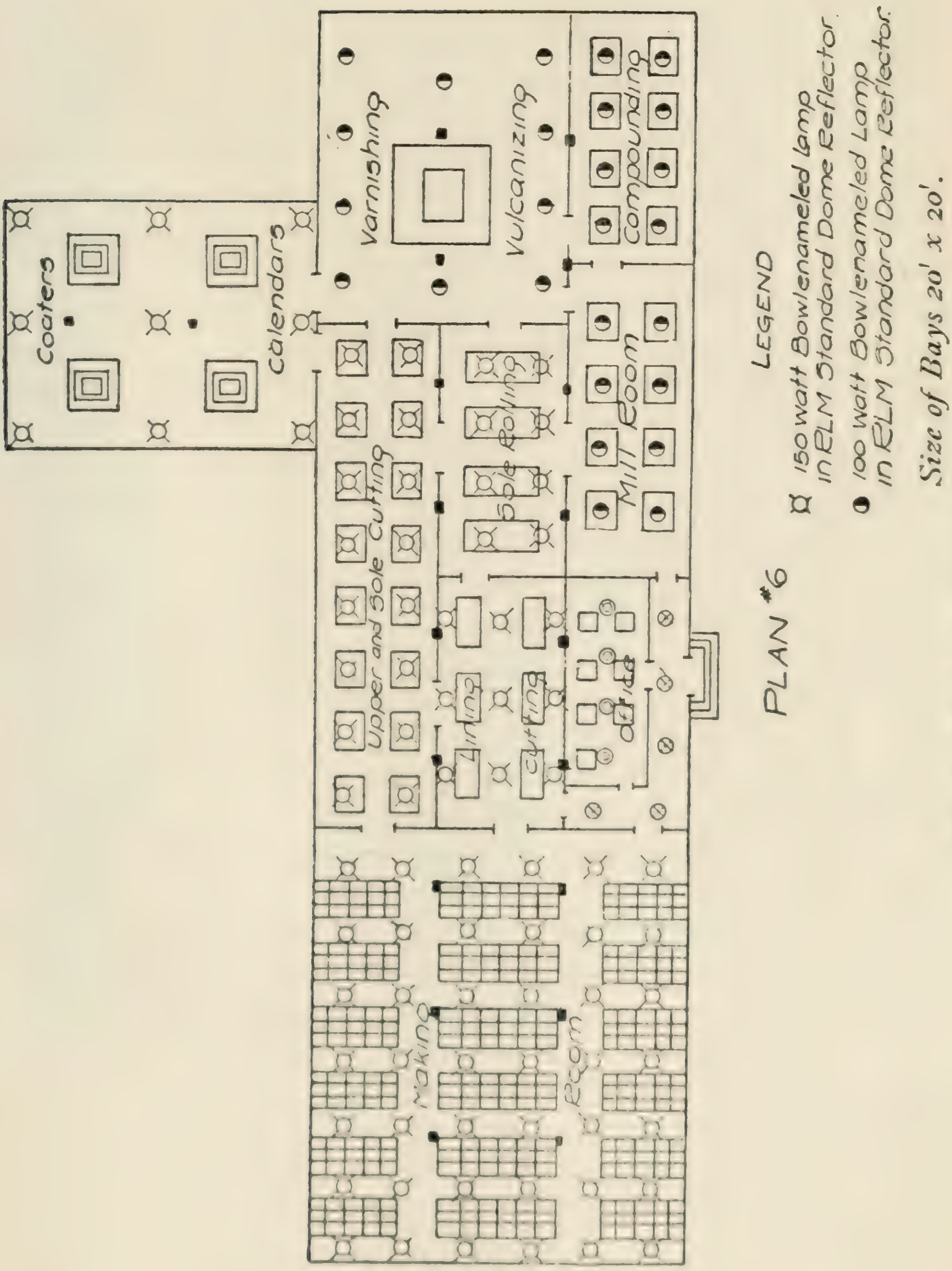


Fig. 18.—Plan of rubber shoe factory.

The distance between the under side of the cast iron beam and the iron platform on which the block rests is from eight to twelve inches. There is a danger of fingers being crushed unless the light penetrates beneath the beam and for this reason it is necessary to place units providing a good vertical component of illumination. Units should also be placed to the rear of the machines, in order to break up the dense shadows cast by the beam on the platform. These machines well lighted are shown in figure No. 2.

The arrangement of machines shown in Fig. 13 could be well lighted by 100 watt bowl enameled mazda C lamps in r.l.m. standard dome reflectors placed as shown. This would provide an intensity of about six foot candles, the wattage allowance being one and one quarter watts per square foot.

In a large plant, most of the space on this floor is devoted to leather storage as indicated in figure No. 1. A strictly symmetrical arrangement using about one watt per square foot with daylight mazda lamps and efficient reflectors is effective in showing up the various shades of the leather.

In this particular plan are shown the last racks which are ordinarily found in the making room. Shelves or bins may be used for this purpose and these usually extend to the ceiling with two or three foot aisles between the bins for the purpose of enabling one to select certain batches of lasts or put back used ones. In the case of bins, the edges usually extend out into the aisles and the sides slope upward leaving a space open at the top wherein are placed the lasts. Light from overhead units easily reaches these open spaces from where the lasts are obtained. Where shelves are employed, however, light from overhead lamps is apt to illuminate only the outer most edges of the shelves leaving the remainder in darkness. In order to avoid this, the width of the shelves should be limited to about four feet and as both sides are open, light can be furnished from each side. Seventy-five watt mazda C lamps in r.l.m. standard dome reflectors on approximately twelve foot centers between rows will light up bins or shelves and enable one to select particular kinds of lasts at will.

The Upper Leather Department is subdivided as follows: ,

Sorting Department.
Trimming, Cutting and Staying Department.
Lining and Cloth Cutting Department.

Upper Cutting Department.
Counter, Marking and Skiving Department.
Assembling Department.

The sorting department as its name implies is devoted to the sorting and grading of various kinds of leather which are used to make up the individual lots of shoes; for instances, when an order is received calling for certain kinds of shoes, the leather which will be used in making these shoes is selected from the assorted grades as to quality, color and grading. This is very important, as it would not do to have shoes widely divergent in quality contained in the same lot. Plenty of light is necessary in sorting, in order to avoid pieces of leather containing bad flaws, such as cracks, scars, etc. Color discrimination makes it advisable to take into consideration the quality of the light.

From the sorting department, the leather goes to the cutting department where skillful workers divide each piece into as many parts as possible. Very little leather is wasted. When dividing the leather prior to cutting, care must be taken to avoid flaws in the leather. After the leather is divided, the cutter then cuts out individual parts which go to make the upper of the shoes. The quality of the light again enters here and wherever possible, the cutting room faces north sky.

The counting department relates simply to the counting of various pieces of leather while marking has to do with the marking of these pieces with their individual lot numbers. Skiving consists of the mechanical application of trimming the edges of the uppers so they can be turned over in order to present a finished appearance. The trimming of the uppers is accomplished by passing them between two edged discs at right angles to each other which, as they revolve, trim the leather to a beveled edge. The lighting requirements for these machines are not exacting.

The work of assembling consists of getting together various parts which go to make up the completed upper of a shoe consisting of the lining, stay, vamp, counter, toes, tips, etc.

Although the upper leather department as a whole is subdivided depending on the operations which are performed, the entire group is contained in one room and can be lighted by general illumination of a suitable intensity for the various processes. The two departments having the greatest demand for lighting are the

sorting and cutting departments requiring high intensities of approximate daylight quality. In both the cutting and the sorting departments the general system of illumination is applicable, but when considering the lighting of the benches along the windows, the units should be placed so as to avoid the operators casting shadows on their work. In order to do this, it will be necessary to place units either on a line with the edge of the table or else between the edge of the tables and the wall.

On the plan No. 2, (Fig. 14) the sorting and cutting departments are seen to be lighted with 200 watt daylight mazda lamps in r.l.m. standard dome reflectors giving about ten foot candles (2 watts per square foot), while 150 watt bowl enameled mazda C lamps in similar equipment are used for the remaining portions of the upper leather department.

Stitching Department.—Divided into:

Lining Department.
Tip Department.
Closing and Staying Department.
Boxing Department.
Top-Stitching Department.
Button-Hole Department.
Stamping Department.
Toe-Closing Department.

This section of the factory is by far the hardest of all to illuminate properly. There are two methods of grouping the stitching machines in vogue at present. One is to run the table on which the machines are mounted from the windows towards the center of the room; from six to ten operators can work at one table with this arrangement, and the light comes from either side, the left or the right. The other arrangement is to have the machines lined up along the windows in two rows, one row placed immediately next to the windows, the second row placed from six to ten feet behind that. The operators in this case, all face the window which is a poor arrangement due to the fact that the light comes from such a direction as to tend to cause eye-strain. The former arrangement is the better for both natural and artificial illumination.

At present, it is the custom to use 25 watt lamps in half shade or bowl reflectors mounted on a goose neck or extension arm

which can be bent and placed in nearly any kind of a position the operator desires. As a result, we see lamps placed about six inches away from the needle on the side opposite to that which the operator adopts with reference to the machine and consequently, the light coming from the lamp, strikes the polished surface of the machine and is then reflected by specular reflection up into the operator's eyes. Needless to say, this arrangement causes impairment of the operator's vision eventually. The operators claim that the lamp must be so placed in order to obtain enough illumination on the working plane. The intensity with this system is from fifteen to thirty foot candles on the working area which is directly beneath the needle.

Numerous attempts have been made to install a general system of illumination in this department, but to date, all such attempts have failed for various reasons. Not only must the proper intensity of light be provided at the working point, but a high degree of freedom from shadows is also necesary. The most logical manner of securing this high degree of diffusion, *i. e.,* by a semi-indirect or totally indirect system, cannot be used because of the low ceiling height and the poor finish of both ceiling and walls. Direct lighting seems to be the only method available for accomplishing the lighting of the machines. Lighting by means of individual lamps has been rigidly adhered to because the many unsuccessful attempts at general lighting have served only to convince plant managers that local lighting is an absolute necessity.

In view of the high intensity really required when stitching on dark material must be carried on, it is somewhat a question as to whether it is economical to attempt to light this part of the plant by the overhead system. There is no question but that it can be accomplished provided sufficient wattage is used and units so located that shadow effects are minimized. To secure the high intensity necessary (estimated at twenty foot candles or more) with efficient reflectors and bowl enameled lamps, in the neighborhood of four or five watts per square foot are required. Local lighting is satisfactory provided a suitable reflector is chosen for the lamp used for this purpose and the units so placed that glaring reflections will not occur. The supporting arm for the local lamp must be of a character that can be readily manipulated and will not wear the insullation on the current carrying wires. The reflec-

tor used should be small so as not to be in the way and should thoroughly shield the eye from lamp filament. Frosting the lamp or providing other means of diffusion is a desirable element. In Fig. 14 a moderate intensity, about three foot candles of general illumination is supplied by 150 watt bowl enameled mazda C lamps in r.l.m. standard dome reflectors, one per bay. Twenty-five watt bowl frosted mazda B lamps with deep bowl aluminum finish steel reflectors designed for this purpose are provided for each machine on a suitable adjustable arm.

The eye-letting, button-holing and perforating machines all have overhanging parts which cast dense shadows on the work from overhead lighting. In the case of the perforating machine, for example, the tips of the shoes are placed in a deep slot and there are punched with the particular design called for. Light from a predominatingly horizontal direction must be provided in order to be useful. For all these machines, therefore, local lamps of the type described are desirable.

The Making Department.—Sub-divided into the:

Vamping Department.
Welt-Bottoming Department.
McKay Bottoming Department.
Heeling Department.
Turn-Shoe Department.
Standard, Screw, Nail or Pegged Shoe Department.

This department which is also known as the bottoming or gang-room usually occupies but one room in the smaller factories, but is divided into the above named departments, each occupying one room in the large factories.

A general characteristic of the machines in this part of the factory is the prevalence of overhead parts and constructions which make the question of direction of light of prime importance. Localized general illumination is therefore quite essential. In the large factories, however, where a single operation is carried on in one room and the machines obviously are of the same type they are arranged in rows or groups as closely as possible and yet permitting freedom of movement on the part of the operators. In view of the symmetric arrangement of machines in this instance, the localized general means of lighting virtually becomes symmetric general illumination.

In the smaller factory all operations are performed in the same room. The machines are lined along the windows in progressive order. The shoe proceeds down one side of the factory each operation bringing it nearer a state of completion. There may be only two, three or four machines of one type in the entire department.

A special study must be made of the lighting requirements of each machine so that the operators, accustomed to working under natural lighting, will receive this character of illumination at the working point. Local lamps find much favor for lighting these machines, not necessarily because they provide a high intensity, but rather that they give the proper directional effect.

With a strictly symmetric arrangement of outlets, the artificial lighting has a predominating direction opposite that of natural lighting, in other words, from the side away from the window.

In the localized general system, a greater number of moderate size lamps rather than a very high powered unit produce the desired effect. Shafting, belting and other overhead construction, together with a low ceiling height add to the complexity of the problem. Individual electric drive machines and the higher ceilinged newer buildings simplify the question of artificial lighting. The central portion of the making room is used as a storage space for shoe racks and a well designed localized general system of illumination for the machines along the walls will provide, under normal conditions, a sufficient spread of light to illuminate this part of the room.

With the exception of the lasters, sole layers, levelers, and nailing machines with which the direction of light is not important, practically all the machines in the making room demand light from the right and rear of the operator. The illumination of vertical surfaces is specially important and a high horizontal component of distribution essential. The actual intensity of illumination supplied will vary with the degree of fineness of the work and is indicated in the accompanying table. In Fig. 15 a localized general arrangement with 150 watt bowl enameled mazda C lamps in r.l.m. standard dome reflectors is shown for this particular arrangement.

Finishing Room.—After leaving the gang room, the shoe proceeds to the finishing room where it is inspected and faults cor-

rected. The work of ironing out wrinkles is performed on a machine known as a treeing machine. This machine has four horizontal arms at right angles to each other and a shoe can be placed on each arm. See night view figure 10. The treer assists in ironing out wrinkles and putting the shoes in shape before handing them over to the final inspectors after which they go to the shippers and packers. The dark color of the goods makes it necessary to have a high intensity of light in order to make a suitable inspection.

For finishing white shoes, a corner of the room is usually set aside. A lower intensity is required for this work because the white finish of the shoe reflects a greater proportion of light than dark brown or reddish shoes. Since this class of work is also carried on in the same room, it would be well, in order to standardize the equipment in that room, to use the same type of installation with perhaps the exception of substituting lower wattage lamps in place of the high wattage lamps required for the dark shoes.

General lighting is entirely satisfactory as there are no overhanging parts. As shown in Fig. 16, two watts per square foot providing from eight to ten foot candles with bowl enameled mazda C lamps in r.l.m. standard dome reflectors is satisfactory. Scourers, burnishers, and polishers are also contained in the finishing room. They also can be well lighted by a moderate intensity (six foot candles) of general illumination provided the ceiling height is reasonably high and racks do not seriously interfere with the light. In the plan shown 100 watt units are employed in this portion of the room devoted to these machines.

Packing and Shipping Department.—The work carried on in this department consists of matching pairs of shoes, inserting laces, numbering the shoes and packing them in individual boxes preparatory to shipping them in crates. This work consists entirely of bench work and the horizontal illumination required can easily be furnished by a general system. Because of the shelves which extend to the ceiling in most cases, it may be necessary to abandon the systematic arangement of lamps in order to provide light where it is needed. The same type of equipment should be adhered to however and as is usual in such cases the plant electrician selects the most suitable positions for such outlets. Where-

ever the chance presents itself the regular spacing of lamps should be maintained as this arrangement insures a much more even distribution of light on the work. Over the aisles between the shelves (as in Fig. 17) 75 watt lamps in r.l.m. standard dome reflectors placed on a line with the top shelf would provide sufficient illumination to expedite such placing and selecting of shoes as may be necessary from time to time.

The paper boxes in which the shoes are packed are either purchased by the factory or manufacturer in their own plant. Such a box making department is shown in figure 12. The boxes are made entirely by machines which are automatic in operation. The lighting requirements are few and simple and can be easily taken care of by a general system such as shown in the illustration. About one watt per square foot of floor area using bowl enameled lamps in r.l.m. dome reflectors is satisfactory (see Fig. 17) .

RUBBER SHOE FACTORIES.

Wash Room.—The crude rubber is cut into small parts by a band saw which should be clearly illuminated to avoid danger of accident. In one of the mills visited, a high powered lamp without a reflector was placed about eye level and close to the saw. It is really strange that the workman has not received a serious injury due to the blinding effect of the lighting. There must have been many occasions when the swiftly moving blade was indistinct if not totally invisible. Such conditions as this about the industrial plant must be watched for and avoided. In the washing process there are no close demands on the vision. It is merely necessary to provide sufficient general illumination to load the crude rubber in the mills and make occasional adjustments. The material is handled in bulk. Safety is the determining factor of illumination. From one half to three quarters of a watt per square foot of illumination will be adequate.

Mill Room.—As shown in Fig. 18, the mills are usually arranged in rows along the sides of the room. With general illumination it is possible to have the outlets approximately over the machines. Bowl-enameled 100-watt mazda C lamps in r.l.m. standard dome reflectors hung ten to twelve feet high will give satisfactory results.

Compounding Room.—General illumination of a moderate intensity is adequate in this part of the plant. From three quarters

to one watt per square foot should be provided. Good lighting here will prevent errors in the mixture and be a paying investment. Where hoods are provided over the compounding machines to carry off the fumes and powdered material local lights beneath the hood in addition to the general illumination are necessary.

Cutting and Calendaring.—As the material passes over these machines, it must be inspected for defects and care must be taken to see that the coating is applied in the correct manner. Good lighting will make this work easier and more certain as to results. Calendars especially, of the three or four roller type must be given particular attention and the light must have a high horizontal component. Overhead units tend to cast deceptive shadows on the work and the operators are then likely to have their fingers caught between rollers and crushed. The general illumination lay-out indicated in Fig. 17 will give good illumination on both sides of the machine and at the same time illuminate the entire area in a satisfactory manner. It will be noted that these are placed at such a distance from the machine that shadows will be largely eliminated. If the room is not so arranged as to make this scheme practicable or there is a multiplicity of shafts, belting and the like precluding the use of general illumination then outlets located at the ends of the machines and lamps equipped with angle type reflectors should be installed. Such an arrangement will give the maximum illumination on vertical surfaces, or in other words on the material as it passes over the rollers.

Drying Room.—After leaving the cutting or cloth-gumming machines, the rolls are placed in the drying room where they are dried by means of steam heat. As there is a possibility of explosive gases being emitted vapor proof units should be installed here. Where portable lamps are used they also should be provided with outer glass casings and suitable guards.

Sole Rolling Machines.—The center portion of most of these machines extend practically to the ceiling and a symmetric arrangement of outlets would probably cast bad shadows. As shown in the plan, in addition to a low intensity of general illumination, always required with local lighting, it is necessary to have relatively small lamps in deep bowl reflectors to direct the light on the work at both the front and rear of the machine. Such an

arrangement will enable the operators to make adjustments with facility and gauge and inspect the stock accurately.

Sole and Upper Cutting.—The operators on these pieces are working rapidly with sharp knives and if the artificial light is of a character that is not well suited, the danger of cutting ones self is increased. A high intensity of evenly distributed light from units equipped with proper reflectors to shield the eye and hung well out of the angle of view is essential. The arrangement shown in the plan will give the maximum illumination at the ends of the boards or tables where the workman stands and yet will not confine the bright illumination to a small circle as in the case of the local lamp which is very trying to the eye. In general, lamps hung close to the ceiling are advisable. Where soles are machine cut, local lamps are often necessary on the machines in order to penetrate to the working point.

Cutting Linings.—Beam dinkers similar to those described under Leather Shoe factories are used for this work and the same methods of lighting apply.

Making Room.—Benches about twenty feet long and six feet wide extend from the windows toward the center of the room. The operators, six to ten on each side of the bench, assemble the complete shoe on the last. The parts are supplied to them already cut into shape and cement is employed to attach one portion to another. The rather exacting nature of the work and the fact that the most of the material is jet black in color necessitates a high intensity of illumination. A shelf or rack at the center of the bench extends its entire length. The lasts are placed on this and if units are hung low over the center of the bench, these projecting elements would tend to cast shadows on the working area. The arrangement indicated in the plan of units hung ten feet or so above the floor over the aisles gives a more desirable distribution of light.

Varnishing and Vulcanizing.—Here again, the work is handled more or less in bulk, although it is practically a finished product. There are no demands for close vision and a moderate intensity of general illumination suffices.

Inspecting and Packing.—These processes are identical with the leather shoe factory and the same methods of lighting apply.

CONCLUSION.

As has been pointed out, it is necessary to know the positions of the various machines before the lighting system can be satisfactorily installed. It is not practical to take the plans of a new building and provide wiring on a basis of four units per bay or some similar scheme. If the conduit is to be imbedded in concrete, provision must be made for future alterations. In the majority of cases where buildings have been so wired on the symmetric arrangement, the overhead system has naturally met with ill favor on the part of the factory men and such situations should be avoided.

The present lighting in shoe factories is not in accord with our present day standard. The need of proper lighting is fully recognized, however, and when systems are installed which meet the requirements of this class of work, their application will be widespread. The United Shoe Machinery Corporation of Boston, which, through the leasing of shoe making machines has a remarkable influence in the industry, is very favorably inclined toward bettering the present lighting conditions. Numerous investigations have been haphazardly conducted with a view to determining what can be done along these lines. Judging from the installations now in service it appears that there is still much chance for further work. The authors are planning to continue the investigation and anticipate raising the present standard of illumination.

A word of appreciation is due the officials of the United Shoe Machinery Corporation and the numerous manufacturers through whose co-operation the investigation was made possible, and Mr. E. F. Carrington of the Edison Lamp Works for his assistance in obtaining the night photographs used as illustrations.

DISCUSSION.

Jos. D. Israel: The thought occurs to me and it has been brought out forcibly by this paper, that we should have standardization. If we who are out in the field selling illumination have the continued benefit of the ideas and suggestions and work of the men who have applied themselves to the lighting requirements of a series of operations in each of the many lines of manufacturing we will have some definite figures that can be presented in a quick, practical way to the ultimate consumer, all of which will help us materially in our daily work.

A. H. Holden: Being interested in the lighting of a large rubber shoe factory, I am wondering if this lay-out has been installed and if so, has it been successful.

I have also wondered about the dimensions of the bay. They are usually 20 ft. by 20 ft., but I would like to check up on that to find out just what the actual illumination was.

Henry Logan: I should like to say that in a shoe factory lighting lay-out which I was recently instrumental in installing at Columbus, Ohio, the scheme used was nearly identical with the one outlined in this paper, and the enthusiastic reports of the superintendent and other executives of the factory, assure me of the success of the installation. However, different equipment (prismatic reflectors and not "r.l.m.") was used.

The management very kindly gave some consideration to my suggestions in placing the machines so that the lighting of them was more easily accomplished than it would have been had they placed them as is customary in the shoe business.

The machines were placed at right angles to the windows, so that daylight coming in from the sides illuminated equally the front and rear of the machines. The artificial lights were then so arranged that the directional tendency of daylight was approximated. In addition to that, the walls, ceilings and all the woodwork was painted with a highly reflecting white paint, competitive tests having first been made to determine the most desirable product.

F. C. Caldwell: We are all interested in the increase in production which may be expected from an increase in lighting intensity. Several years ago, one of my students while studying this question thought he had a fine opportunity to get some data in a shoe factory, where they were just installing a new system of illumination. This included local lights on the machines, with a very large increase in illumination on the work.

He has obtained the piece work data on production before the improvement was made. Two or three weeks afterward he was surprised to learn that there had been absolutely no increase in production. He talked with the girls who were doing the work and found they were much pleased with the new lighting; they told him that they did not have to work nearly so hard as before.

J. B. KELLEY: There is one point in shoe factory lighting outside of production that is extremely worth while, and that is, in reducing the crop of cripples (cripples meaning defective products). At a certain shoe factory for which I planned the lighting installations a few years ago, while not using the intensities deemed necessary to-day, yet nearly up to the present standard; the number of cripples was reduced in point of volume and also character. The cripples previous to that time showed all kinds of defects. Since the new lighting was installed, the cripples lesser in quantity are either very bad or just slight. There are no middle class cripples.

A. L. POWELL: The plans represent to a greater or lesser degree, a hypothetical case. We did not encounter a factory lay-out exactly as shown here, but the methods shown have all been applied in individual factories, and correlated in these plans.

It should have been indicated that the bays were 20x20 feet.

It is indeed gratifying to us to receive Mr. Logan's comments in view of the fact that we certainly worked independently and his investigation has also brought out a number of features that have struck us as extremely important, that is, the rearrangement of machines and the element of diffusion.

Our intention was to make the lay-out applicable to all types of reflectors having the same general over-all efficiency, the r.l.m. dome, the prismatic and dense opal bowl reflectors. We happen to specify the r.l.m. dome because that has become the more or less standardized product but the methods are certainly applicable to other equipment.

TRANSACTIONS
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PART II -- PAPERS

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PLEASING PROPORTIONS OF DIRECT AND DIFFUSED LIGHT FROM A FLOOR LAMP.*

BY J. R. CRAVATH.

ABSTRACT.—This paper gives the results of preference tests, on 25 observers, as to the most pleasing proportions of direct and diffuse light from a floor lamp under certain specified conditions in a given living room. Direct light under the lamp was constant and the diffuse light varied. Curves and tables show the range of illumination and brightness offered, the proportions preferred, and the distribution of the light flux about the lamp with the most popular proportions. Results are discussed, taking cognizance of other tests and factors.

The object of this paper is to give results of tests to determine pleasing proportions of direct and diffused light under certain specific conditions. The tests were undertaken to throw light on a specific problem and should not be applied to conditions other than those surrounding these tests.

The specific problem was as follows:

Given a living room of approximately average size and finish, for the lighting of which a single floor lamp is to be provided as the principal every night source of illumination, and assuming that the direct light from such a lamp is to be sufficient for the most severe requirements of close work in a living room, what amount of general diffused lighting is required to produce the general effect which will be most pleasing to the majority of possible purchasers and users? Problems of this kind have heretofore been solved largely according to the whim of the designer or the taste of some official of the concern making the lamp. The present tests were designed to determine what is artistically pleas-

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ing to a majority of individuals, with the idea that the results might be used as a foundation for engineering designs of lighting appliances to reproduce pleasing effects with certainty and efficiency, rather than by cut and try guess work. It is not to be assumed that the results throw light on the problem of light distribution from pendant fixtures.

The majority of people, by life long training or association of ideas, expect a somewhat different effect from a floor or table lamp than from a central pendant fixture. We associate portable lamps with strong localized lighting and very much subdued light in the rest of the room. Of course such results can also be obtained from central pendant fixtures by proper design, but they are not generally obtained or expected. There is also the very important practical reason why much more general illumination is expected of a central fixture than of a floor lamp, namely, that the central fixture can not be moved to any part of the room desired, and consequently it must give enough general illumination to answer practical requirements anywhere in the room, whereas the portable fixture can be moved for these utilitarian purposes.

PLAN OF TESTS.

The tests were conducted in a living room, plan of which is shown in Fig. 1. A photographic view of this room is shown in Fig. 6. This room had a ceiling nearly white, slightly cream; walls yellow; natural oak wood trim and floor finish; and brown predominant in the rug. It would commonly be classed as generally light in tone.

The test floor lamp, which is located at L, Fig. 1, and shown in its test position in Fig. 6, was so constructed that the direct light was limited to a cone of about 38 degrees from the vertical, and was approximately constant. Indirect light was emitted from the top of the lamp in varying amounts through screens made of tracing paper, the number of thicknesses of which was varied to give 15 geometrically progressive steps. The general plan therefore was to keep the direct component of light constant and vary the indirect component, according to the tastes of the various observers who were tested. The tracing paper screens were simply laid on top of the shade of the floor lamp, and consequently

acted both as absorbers and diffusers. With the screens removed the cut-off line of the cone of indirect light was about 28 degrees above the horizontal.

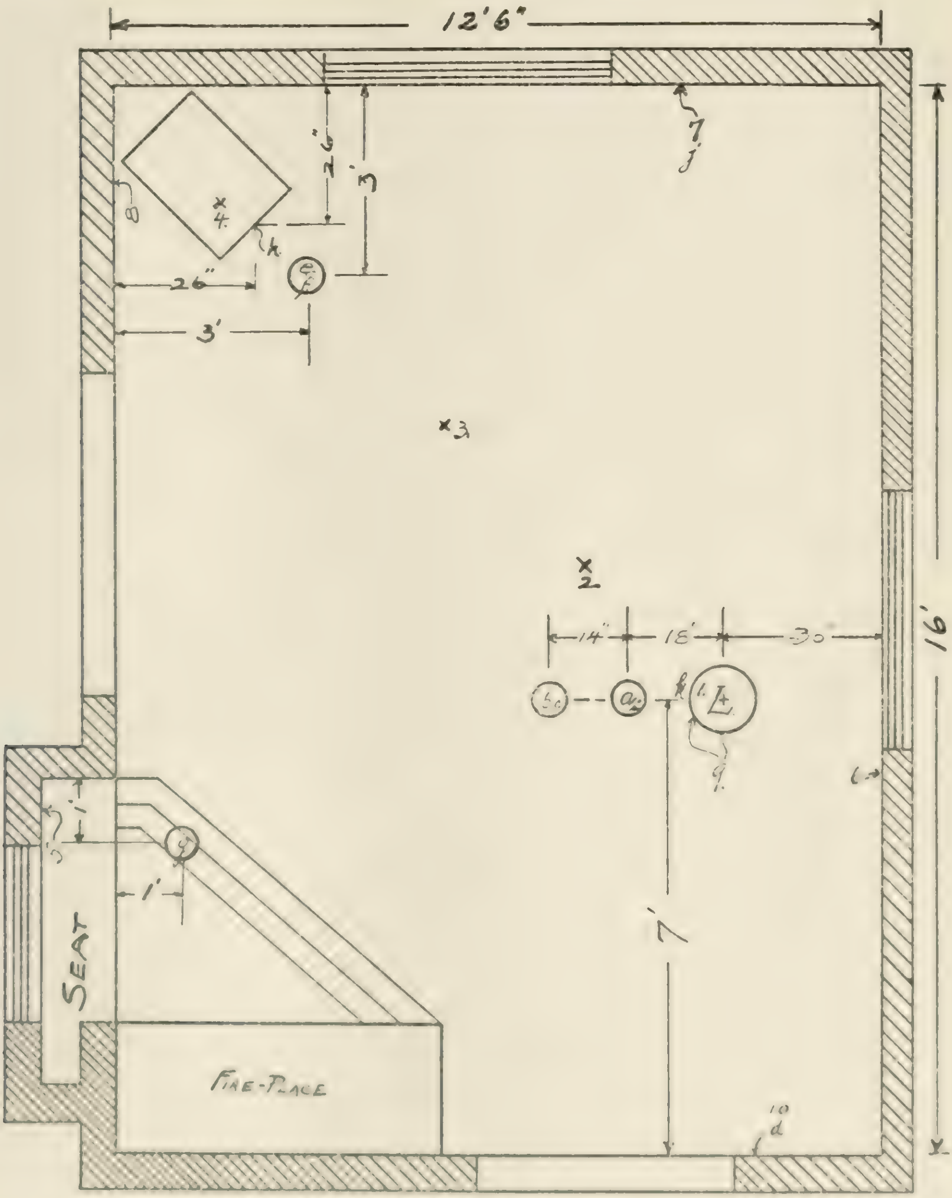

Fig. 1.—Plan of living room.

The lamp filament was 66½" above the floor. The cut-off of 38° for the direct light was determined upon by experiment as that which would give a sufficiently wide zone of localized light for reading or sewing in comfort, for anyone seated close beside the lamp, and at the same time not so wide as to destroy the cozy effect of localized light.

The shade of this improvised floor lamp consisted simply of a cylinder of heavy yellow drawing papers which gave a pleasing color effect, which was favorably commented upon by several of the observers, who were unaware by what homely methods the result was obtained. Plans were at first made to use an opaque black steel cylinder for the lamp shade, but after trial of this opaque cylinder it seemed best to substitute something slightly translucent, more nearly like a common floor lamp, as the opaque shade seemed to introduce something into the general effect which was unnatural and interfered somewhat with making a judgment of the general lighting effect in the room. As it was found that the brightness of the interior of the lamp shade, as seen by persons seated about the room, was so high as to introduce a distracting element, a cone of drawing paper was inserted in the bottom of the lamp shade so as to shield this brightness from the eyes, and incidentally cut down the direct component to the desired point. A 200-watt lamp upright was used.

It will be seen from this description that this experimental floor lamp was in no sense a commercial appliance, and that the general plan was to start with a source giving much more than the required light flux and cut down the excess flux in any direction as desired.

As before stated, all of the tests were made on an approximately fixed direct component of light for the use of persons seated near the lamp, as in Position a, Fig. 1. This direct component is considerably higher than commonly prevails with floor lamps, being about 15 foot candles. This quantity of illumination was selected as being the maximum amount ever likely to be required for useful purposes in a living room. The majority of people will consider three to four foot candles ample for reading. However, there are individuals, especially the aged, with vision below normal, and these, to be contented, want more than three or four foot candles for reading. The most severe requirement of localized lighting in the living room however, is that of hand sewing or mending on dark goods, for which from eight to twenty foot candles is very acceptable. For such work direct light, which will give some specular reflection from the thread, is desirable.

The observers comprised eleven men and fourteen women of ages ranging from 16 to 67, friends and neighbors of the writer.

Each observer was tested as follows: The observer was first seated at the fire place seat, Fig. 1, where there was a good view of the room as a whole. The observer was asked to pass judgment on the general effect which was most pleasing of the various effects to be shown. If, as sometimes happened, the observer made the point that there should be one effect for use if a number of people were in the room on special occasions, and another if only one or two were using the room, the observer was then asked to select the effect which was most pleasing, on the assumption that the floor lamp would be used most of the time for reading and for casual visiting, but that on special occasions more general lighting might be used. With this explanation the test was begun by showing the lightest and the darkest effects obtainable, to determine in which direction the observer's preference lay. From that on the choice was narrowed down to such small differences that the observer had practically no preference. Decisions were usually arrived at very quickly.

The observer while seated in the first position beside the fire place, was next asked to pass judgment on increased or decreased brightness of the lamp shade. This was done by adding layers of paper to the shade and was done with the room illuminated with the proportion of direct and diffused light which the observer had already selected from his position at the fire place seat. This part of the test was purely a judgment on the pleasing effect of the shade itself, as the additional thickness of the shade and the consequent decrease in brightness had very little effect on the general illumination of the room. The first test on each observer was run with the shade brightness of 10 to 12 millilamberts, which in some preliminary tests was indicated as being about the average brightness which would probably be required, and would not therefore introduce any materially disturbing element into the direct and diffused light test.

After completing the two foregoing tests, the observer was then asked to sit in a chair by the floor lamp, to take a book in hand to read, and by a process similar to that applied in the first test, to select the surrounding room brightness which the observer felt would be most pleasing were he to be using the floor lamp for

reading without visitors in the room, no consideration being given to the quality of the direct light on the reading page.

It will be seen from the foregoing description that this test was essentially a snap judgment test based on first impressions and on the instinctive feelings of the subject tested. It should not be confused with tests for eye fatigue or for the physiological effect of the continued use of various proportions of direct and diffused light.

The amount of diffuse illumination selected by the greatest number of observers having been determined, a laboratory test was made of the floor lamp equipped as during the test with three screens and a shade brightness of 10 to 12 millilamberts, this being the most popular combination.

The range of choice as to quantity of diffused light offered to each observer is shown by the curve, Fig. 2, which gives the vertical illumination at point *d* on the wall, (indicated in Fig. 1) for the floor lamp as equipped with 1 to 15 screen layers, and with an opaque screen with white surface. No observer wanted more or less than these limits offered. Only one selected the upper limit, but he declined an offer of more diffused light than this. Tests were also made of the brightness of the ceiling immediately above the lamp, with the entire range of screens, which curves were in substantial agreement the vertical illumination on the wall at *d*. The results with the opaque screen indicate considerable diffuse light from the floor.

In Fig. 2 the numerals above the curve are the number of the observers choosing those respective points when seated at the fireplace seat, and the numerals below the curve are for observers seated beside the lamp.

The brightness of lamp shade offered the observers for choice ranged from 12 to 2 millilamberts. Here, however, no attempt was made to cover the entire range of possible choice, as the brightest shade represented good practice, from a glare standpoint, and appeared to be bright enough to be satisfactory to all. While a number chose the brightest shade, none asked for anything brighter and all choosing it hesitated between it and darker shades.

636 a

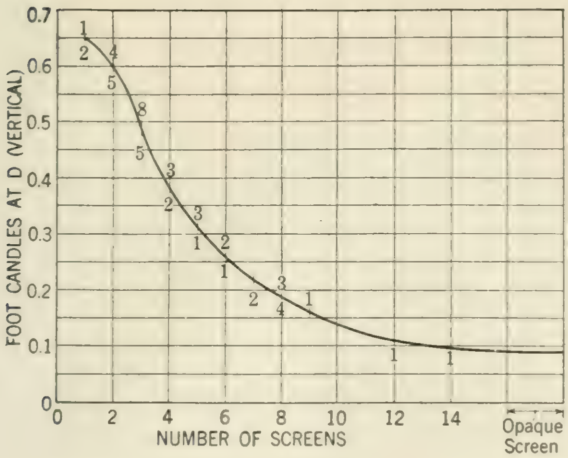

Fig. 2.—Range of choice of diffused light.

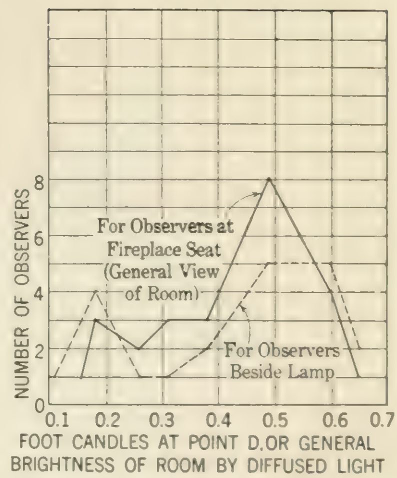

Fig. 3.—Observers choosing the various degrees of diffuse illumination.

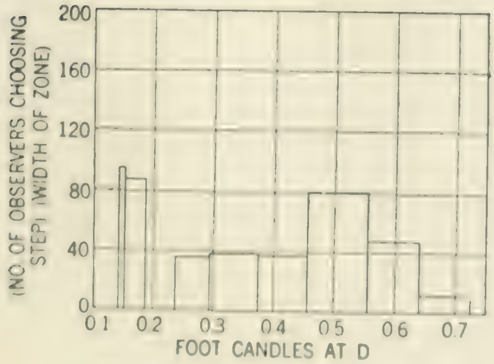

Fig. 3a.—Observers seated at the fireplace.

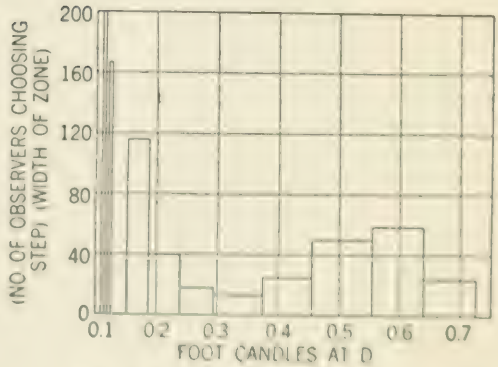

Fig. 3b.—Observers seated beside the floor lamp.

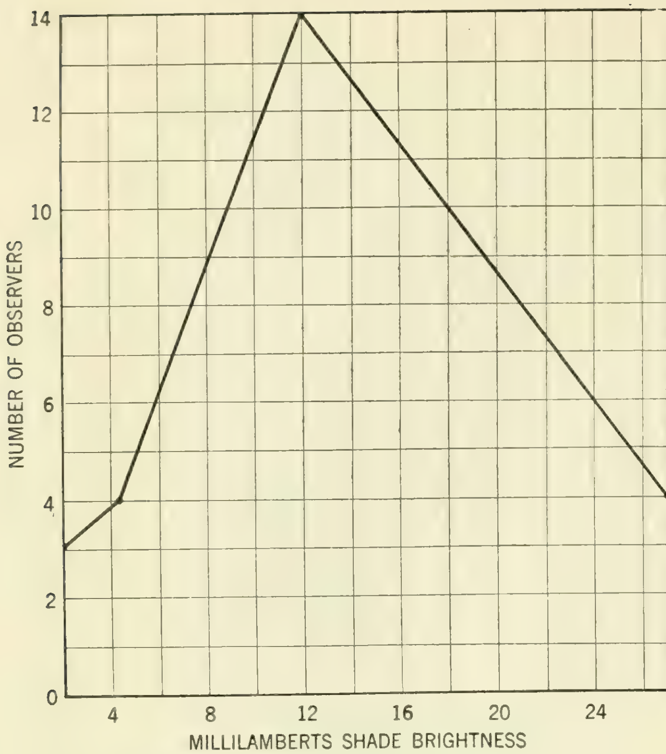

Fig. 4.—Choice of shade brightness.

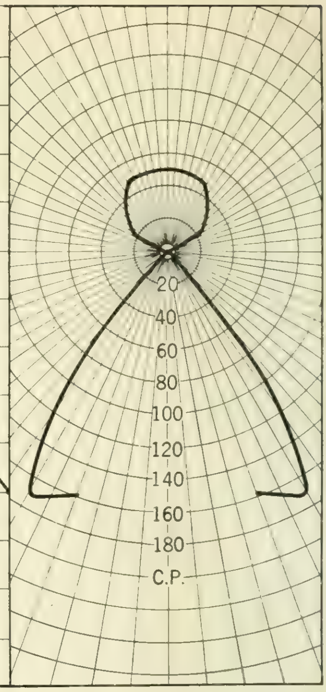

Fig. 5.—Most popular distribution of light.

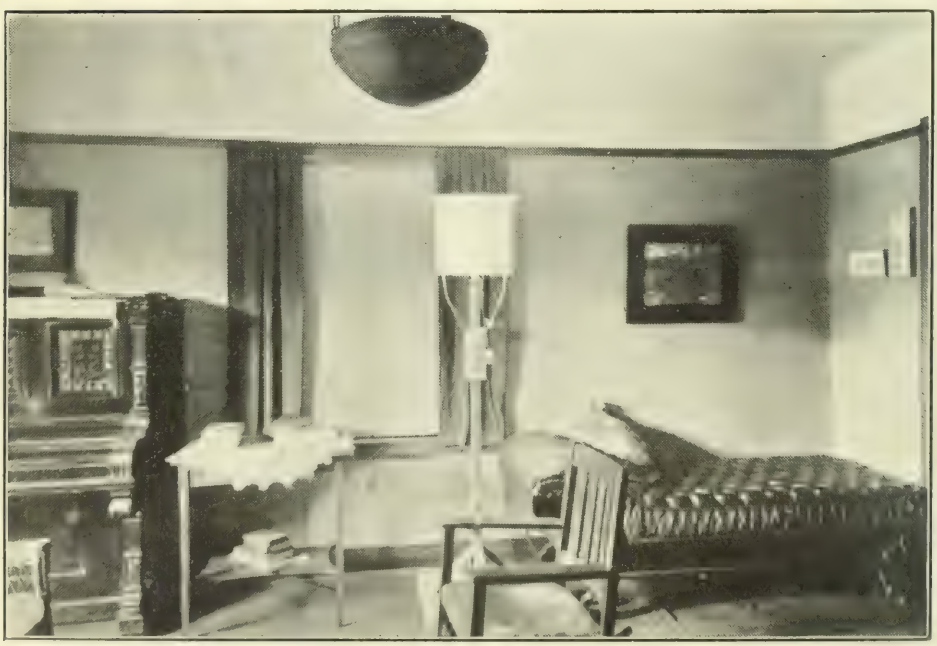

Fig. 6.—Living room and floor lamp.

All illumination and brightness readings were corrected to a uniform circuit voltage of 113, that being nearest the average voltage while observers were being tested.

TEST RESULTS.

Fig. 3 shows a curve of the number of observers choosing the various degrees of diffuse illumination, the relative measure of diffuse illumination adopted being the vertical illumination at point *d*. In Table I, in the column marked "3 Screens," is given the illumination as measured at the various specified positions for the value of diffuse light chosen by the largest number of observers. The test positions referred to in this table are shown in the plan of the room, Fig. 1. This table also shows such details as to location of the test point as could not be given on the plan. Table II gives similar information to Table I, as to brightness of various points in the room. Illumination tests are designated by letters and brightness tests by numbers. In Table I illumination values are also given for the upper and lower limits (1 and 15 screens) which were offered for choice to each observer, as well as for the most popular degree of diffuse illumination. Table III gives observers' choices, both for the position at the fire place seat and for the position reading beside the floor lamp. The same information as to quantitative values is given in the curves, Fig. 3, but inasmuch as these curves give no intimation of the choices of any one observer at the two different observation positions, Table III is given for the purpose of showing how each observer's choice differs at the two positions. Fig. 4 shows the curve of choice of shade brightness in which shade brightness is plotted against the number of observers selecting that brightness. The brightness of the visible part of the inside of the shade was 24 millilamberts. The results of the laboratory test, showing the light distribution from the lamp which proved to be most popular, are given in Fig. 5 and Table IV. To explain the apparent discrepancy between the candlepower distribution curve of the floor lamp and the horizontal illumination at point *a*, it should be said that the curve of candlepower distribution is the average of tests taken in two vertical planes only, and that the candlepower in the direct light zone varies considerably in different planes. The tests at "a" position in Table I happened to be at one of the low points.

DISCUSSION OF RESULTS.

Speculative comment on these results might be carried on at great length. However, as the object of this paper is to present results rather than speculation as to the reasons for the results, only a few comments are called for.

In Fig. III, solid line curve, the preferences of the observers seem to be consistently centered around the choice of the largest number in the tests made with the observers at the fire place seat having a general view of the room. For the tests with observers seated beside the lamp reading, (see broken line Fig. 3) while the general results are about the same as for the first observation position, there is less consistency in the curve, and one small group appears to want the room relatively dark when reading. It is unfortunate that a larger number of observers could not have been tested in both these positions, but from the limited number tested and from conversation with the observers during the test, the writer gained the following impressions, which further investigation may or may not prove correct.

In the writer's opinion much more weight can be attached to the tests made on observers seated beside the fire place and having a general view of the room, than to tests made beside the floor lamp. In fact the latter were introduced merely to throw a little side light on the problem. The tests in the first position are largely impressions as to the pleasant and satisfactory effect in the room, which is what we were seeking in this test. The test from the reader's position beside the lamp was less spontaneous, more mixed with prejudice and theory, and as shown give less consistent results. Furthermore, it is impossible to make a good snap judgment on pleasant and comfortable reading conditions, and in this test only one of the elements of comfortable reading was considered, namely, first hand impression of comfortable illumination of the surroundings.

The tests on satisfactory reading conditions to be conclusive should cover hours rather than minutes of use and should be measured by a Ferree test, or something of the kind for eye fatigue, as well as by the general impression of the observer at the close of each period of use.

Of those who chose the lightest surroundings for reading, one stated that he knew from experience with his own weak eyes that

the violent contrast between page and surroundings was trying. Another, a physician, admitted prejudice because of professional knowledge, that such a violent contrast as existed between the reading page and the surroundings when the room was darkened, was trying on the eyes. On the other hand, some of those who chose the darkened room expressed a feeling of relief offered the eye by looking up into a darkened room from a bright page. Some thought the effect more cozy with the room darkened and strong local light. As to which of these theories of eye comfort with contrast is correct, is rather doubtful at the present time, although brightness conditions in nature and all tests made so far on extreme brightness contrast in range of vision, would indicate that those selecting the higher general illumination of the room and less contrast are correct. There appeared to be no relation between the choice made by an observer in this test and the type of lighting to which the observer was accustomed at home.

Somewhat similar tests have been previously made by F. C. Caldwell and W. M. Holmes, of Ohio State University, and reported in a paper, entitled, "Preferred Proportions in Combining General and Localized Lighting."[1] These Caldwell and Holmes tests were made in a perfectly bare room with dull black walls, without furniture and with the observer seated beside the source of localized light. The indirect light was observed from a ceiling almost uniformly illuminated from wall boxes.

In the Caldwell and Holmes tests the observers, 100 in number, were asked to give attention to the reading page to see whether the reading conditions were good, as well as to glance around the room for a pleasant general effect.

These tests resulted in favor, under the conditions tested, of having 55 to 60 per cent. of the light on the reading page indirect, which of course is far in excess of approximately 10 per cent. in the present tests.

The results obtained in this test, as compared to the Caldwell and Holmes test, seem to justify the assumption made at the outset, that the majority of people expect a somewhat different performance from the floor lamp than from fixtures for general lighting. At any rate, the popular demand for floor lamps in the

[1] Transactions Illuminating Engineering Society, Vol. XIII, No. 6, August, 1918, p. [illegible].

last few years, with most of which lamps an indirect component of 55 to 60 per cent. is impossible, indicated the desirability of investigating further before accepting these percentages as the ones most likely to be acceptable to the purchasers of floor lamps.

In the interpretation of these tests and their application to the design of floor lamps, the following points should be kept in mind as indicating the desirability of modifying the conclusion of these tests in practical designs.

1. A greater percentage of diffuse light would probably add to the comfort of reading.

2. The test room was lighter in general color than the average, so that more diffuse light should be provided.

3. The general illumination around the room called for by the results of these tests, while pleasing in general effect, is rather low for practical utility, for such purposes as occasional reading of a few lines, changing of phonograph records, lighting pictures, etc.

The curve, Fig. 6 and the Table IV, giving distribution of light flux which proved to be most popular, show characteristics which, as far as the writer knows, are not possessed by any floor lamp on the market to-day. The chief peculiarities of this distribution are the small flux at and near the horizontal, and the large amount of flux below 40 and above 120 degrees.

The total amount of light flux emitted from the unit (362 lumens) is surprisingly low, considering the high degree of local illumination and the satisfactory general illumination of a room of this size. A 75-watt, 865-lumen lamp in a unit of 42 per cent. efficiency would give the 362 lumens required.

The majority of floor lamps if of the umbrella type now in vogue, would give much less indirect component, and the direct component would generally be distributed over a much wider area, frequently at the expense of the eyes of those sitting about the room facing it. At the same time, the intensity of the light near the lamp, for reading and sewing, would be much less.

CONCLUSION.

The only sweeping conclusion which the writer wishes to offer at the close of this paper, as a result of these tests, is that there is a real need for illuminating engineers and artists and decorators to work together on portable lamps, rather than to leave the matter entirely to the artists and decorators, as has been largely

done in the past. The portable lamp is not merely a decorative appliance, but in the majority of homes must combine both beauty and utility to be of the greatest service. Up to date, we have had a kind of one sided development in which the appearance of the unlighted lamp rather than the beauty and usefulness of the general lighting effect and of the lighted lamp has been considered.

Both in the planning and routine of these tests the writer has been assisted by Austin M. Cravath.

TABLE I.—ILLUMINATION TEST POSITIONS AND RESULTS.

Position	Horizontal or vertical	Height from floor	Foot candles			
			1 Screen	3 Screens	15 Screens	Opaque screen
a	Hor.	30″	15.6	14.9	14.5	——
b	Hor.	30″	1.64	1.32	0.78	——
c*	Hor.	30″	1.09	0.51	0.14	——
d	Vert.	5′	0.64	0.48	0.12†	0.0887
e	Hor.	30″	0.323	0.156	0.019	——
f	Hor.	0	0.250	0.169	0.033	——
g	Hor.	30″	0.278	0.179	0.033	——
h*	Vert.	4′	0.317	0.199	0.049	——
i*	Hor.	30″	1.45	1.18	0.610	——
j	Vert.	60″	0.35	0.24	0.070	——
k*	Hor.	0	—	4.98	——	——

c*—Shaded from lamp shade.
h*—On phonograph front.
i*—Shaded from lamp filament.
k*—On corner of lamp base. † 14 Screens.

TABLE II.—BRIGHTNESS TEST POSITIONS AND RESULTS.

Position number	Kind of surface	Height from floor	Millilamberts		
			1 Screen	3 Screens	15 Screens
1	Ceiling	8′ 6″	11.3	6.8	0.70*
2	Ceiling	8′ 6″	—	1.19	—
3	Ceiling	8′ 6″	—	0.21	—
4	Ceiling	8′ 6″	—	0.05	—
5	Wall	5′ 0″	—	0.08	—
6	Wall	5′ 0″	—	0.28	—
7	Wall	5′ 0″	—	0.09	—
8	Wall	5′ 0″	—	0.04	—
9	Lamp shade	5′ 6″	—	11.23†	—
10	Wall	5′ 0″	—	0.17	—

* 14 Screens.

† Brightness chosen by greatest number of observers.

TABLE III.—OBSERVERS' CHOICES.

(Comparison of the two positions.)

Observer No.	No. of screens Position No. 1	No. of screens Position No. 2
1	3	2
2	9	12
3	3	7
4	5	4
5	3	3
6	4	2
7	4	8
8	6	6
9	5	7
10	5	4
11	3	3
12	6	2
13	3	1
14	8	3
15	2	3
16	3	8
17	1	1
18	3	—
19	8	8
20	3	5
21	8	14
22	2	3
23	2	2
24	4	8
25	2	2

TABLE IV.—SHOWING THE MOST POPULAR DISTRIBUTION OF FLUX FROM THE FLOOR LAMP.

Angle	Lumens	Group lumens	Per cent.
0			
10			
20	59.30		
30	92.10	190	52.5
40	38.70		
50	7.46		
60	3.66		
70	2.55	25	7
80	2.16		
90	1.86		
100	7.41		
110	14.55		
120	21.75		
130	26.80		
140	28.40	147	40.5
150	26.30		
160	18.35		
170	9.50		
180	1.19		
	362.04	362	100

DISCUSSION.

A. M. CRAVATH: As the method of plotting results, shown in Fig. 3 of the paper, may be somewhat misleading (because the differences between steps of brightness offered were greater at one end of the range than at the other), I have prepared, since the paper went to press, another graph which gives a more accurate picture of the results. A glance at Fig. 2 in the paper shows that there was more difference between adjacent steps when the proportion of diffused light was high than between steps when the proportion of diffused light was low. This of course means that those desiring the higher values of diffused light had fewer steps to choose from than those desiring the lower ones, and consequently at the high values the number of observers per step was relatively greater than if the steps were uniform. In Figs. 3a and 3b I have attempted to compensate for this as follows. I have assumed that under the conditions of the test each observer preferred a certain definite value of diffused light and that he chose the step nearest to it. The observers choosing any step are therefore those whose preferances lie within a zone bounded by values half way between that of the given step and those of the next lower and higher steps. What is desired is presumably a curve giving the number of observers per step for a series of equally spaced steps, which means a series of equal zones. If we had offered for choice a series of uniformly graduated steps with small zones, the average number of observers per small zone, within the limits of any one of the zones we actually used, would be the number of observers choosing the actual zone divided by the number of small zones within the actual zone. Since the small zones are equal, the number of small zones in an actual zone is proportional to the width of the actual zone, and the number of observers per small zone is proportional to the number of observers per actual zone, divided by the width of the actual zone. Therefore, if a graph is prepared from the results obtained from a series of irregular steps by finding the zone widths corresponding to each step, dividing the number of observers choosing each step by the width of the corresponding zone, and taking the value thus obtained as the ordinate of the graph within that zone, we should have a close approximation to what is wanted. Fig. 3a shows such a graph for observers at the fireplace seat, and Fig.

3b for observers seated beside the floor lamp. The area of each rectangle in Figs. 3a and 3b obviously represents the number of observers choosing the corresponding step.

In preparing Figs. 3a and 3b, the foot-candle values for the different steps were taken from the test data, and not from the curve in Fig. 2 of the paper, which has been smoothed out; the plots of the actual observations, all of which lie near the curve, having been omitted.

F. C. CALDWELL: I am naturally interested in this subject on account of the work which W. M. Holmes and I did upon it in 1917. One thing that strikes me is the fact which was also brought out in our tests, that quite definite preferences in these matters may be expected, although at first we were doubtful whether this would be the case.

I want to emphasize the difference between Mr. Cravath's problem and ours. His tests were made with a floor lamp in the living room, while ours were made in a working room where high intensity is needed for close work. In both our paper and Mr. Cravath's, it is emphasized that a special case is considered and that the data should not be taken as general; it was to be expected that the data in the two cases do not agree. That brings me to the point that there is much room for further work along this line. Moreover, this seems to be another case that particularly adapts itself to work in colleges, where one can easily assemble a large number of rather well trained observers.

GEO. G. COUSINS: The author's tests were conducted under light-colored ceiling and walls and the conclusions indicate that about 10 per cent. of indirect light is desired on the reading page, whereas the Caldwell and Holmes test results indicate a preference for from 55 to 60 per cent. indirect light. I would like to ask the authors if they would expect different proportions of indirect to direct light with dark walls.

F. C. CALDWELL: Since that questions seems to apply particularly to our work I might say that we did try it with practically black walls as well as white and arrived at practically the same results.

AN IMPROVED METHOD FOR THE ILLUMINATION OF MOTION PICTURE THEATERS.*

BY L. A. JONES.

In the early days of the motion picture industry, it was customary to present pictures in a room containing practically no illumination other than that resulting from the light reflected from the screen. This procedure may have been justified to a certain extent at the time because screen illuminations were very low, making it necessary to exclude practically all light from the room in order that the resultant picture might appear to be of satisfactory brightness. With the progress in development of projection apparatus, the screen brightness has been raised continually until at the present time such values are relatively high. Improvements in the quality of the photographic materials have resulted in better positives for projection which also tend to give pictures of greater clearness and brilliancy. Along with this tendency to increase the screen brightness, modifications of the interior illumination of motion picture theaters have taken place. The trend has been in the direction of increased room illumination and with the appearance of the higher class theaters, devoted exclusively to the exhibition of motion pictures, has come considerable development in the art of interior illumination of such places. The existence of higher screen brightness naturally permits of greater illumination without serious interference with the quality and brightness of the projected pictures.

The desirability of providing sufficient illumination for the convenience and comfort of the audience, if this can be accomplished without perceptible loss of quality in the projected picture, is obvious. It is scarcely necessary to enumerate the many serious objections to the use of very dimly lighted rooms in which motion pictures are being exhibited to large audiences. The difficulty

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encountered by persons entering from the relatively brightly lighted exterior regions in finding their way to unoccupied seats is considerable. The undue strain thrown upon the accommodation processes of the retina resulting from a sudden transition from a brightly lighted exterior to a dark interior or vice versa is very objectionable and to be avoided if possible. More serious than these, however, is the excessive visual fatigue and eyestrain resulting from a prolonged observation of the brightly illuminated area (such as the screen on which the picture is being projected) occupying but a small portion of the field of view, surrounded by very dark areas, this condition being ideal for the production of glare effects due to excessive contrasts. Furthermore, in such dimly lighted interiors, it is quite impossible for the management to supervise adequately the conduct of individuals in the audience, a fact which has led to some criticism of such places of entertainment. It is evident for the satisfactory exhibition of motion pictures that the general illumination in the theater must be subdued in order that the projected picture shall be of good quality as regards its apparent brightness and contrast, and that in raising the value of the general room illumination there is a limit beyond which it is impossible to go without seriously affecting these characteristics of the picture.

While a great deal has been done in improving the character of the illumination of such theaters, the problem seems to have been approached largely from the purely practical standpoint with the object of producing artistic effects, and for the enhancement of the ornamental detail of the interior rather than with the idea of producing maximum visual comfort for the audience while at the same time maintaining satisfactory photographic quality in the projected picture. It, therefore, seemed worth while to approach this problem from the standpoint of the retinal sensibilities, and to link up the conclusions drawn from such a consideration of the subject with those resulting from practical tests.

From a consideration of the available data relative to the various sensibilities of the retina to brightness and brightness differences, it is evident that a picture having a definite objective contrast may in some cases be made to appear more contrasty if observed under different conditions of illumination. For instance, if the conditions of viewing are such that the retina is operating

at a low adaptation level such that its sensibility to contrast (*i. e.*, brightness difference) is small, enhancement of the apparent contrast can be obtained by so changing the conditions of illumination that the retina is operating at a higher level where its sensibility to contrast is greater. Applying this reasoning to the case of an observer in a motion picture theater, it seems reasonable to assume that it might be entirely possible by using an increased amount of general room illumination to make the projected picture appear more contrasty than with a smaller amount of such illumination. On the other hand, any attempt to raise the level of illumination in the body of the theater will most probably result in an increased amount of scattered light incident upon the projection screen, which since it is superimposed equally on both the high-light and shadow regions of the picture will result in a lowering of the actual objective contrast. From purely theoretical considerations, therefore, it would seem that the use of higher illumination levels in a motion picture theater will result in two effects which operate in opposite directions upon the apparent contrast of the picture being projected.

It seems possible, therefore, that the illumination levels in the body of the theater may be raised to levels much higher than those customarily used at the present time without in any way interfering with the apparent contrast of the projected picture. It also follows that with the higher adaptation levels the apparent brightness of the picture will be less than at the lower adaptation levels, but since screen brightnesses at the present time are relatively high, a slight sacrifice in the apparent brightness can be made without serious results. In fact, in many theaters the high-light portions of the pictures are so bright as to cause visual discomfort, and a more pleasing effect may result if such pictures were viewed with an eye adapted to a higher brightness level. This brief consideration of the fundamental characteristics of the retina makes it possible to draw certain general conclusions as to the most desirable conditions of illumination for the purpose. The data available, however, are not sufficiently complete to permit the computation of the desired values, and hence it is necessary to resort to experiment and actually to measure in an experimental installation the illumination which is permissible, the permissible illumination being defined as the maximum illumination

which may be employed without causing a perceptible loss of quality in the projected picture.

Before proceeding with an account of the experimental work, it may be well to consider in more detail the general theory of the subject and the fundamental characteristics of the eye which are important in problems of this nature. First of all, it should be borne in mind that the sensation produced when light falls upon the retina depends upon several factors such as the intensity of the light, the length of time during which the stimulation continues, wave length of the radiation, the size and shape of the retinal area stimulated, and the physiological conditions of the retina due to previous action of light upon it. It is sufficient for the present purpose to consider only the reactions of the retina to the intensity factors of the stimulus and neglect those which are functions of its quality.

Of first importance among the factors requiring consideration is the sensibility of the retina to brightness. There are three types of brightness sensibility, (1) threshold sensibility, which is measured by the least brightness perceptible, (2) contrast sensibility, which is measured by the least brightness difference perceptible, and (3) glare sensibility, which is measured by the brightness just sufficient to produce discomfort when observed.

Now the sensibility of the eye to brightness, contrast, and glare depends upon the condition of the retina at the particular time the determination is made, and that condition is in turn dependent upon the previous stimulation. Hence, it is necessary to specify the condition of the retina at the time the measurement of sensibility is made. This is done by specifying the brightness, to which the eye is adapted, and is termed the "adaptation level" of the retina. For instance, when an observer looks for some time (10 to 30 minutes) at a uniformly illuminated surface so large as practically to fill the field of vision, a condition of equilibrium in the retinal process is reached, and the observer's eye is said to be adapted to the brightness of the field, and his "adaptation level" is specified by stating the brightness of the illuminated surface, which is sometimes termed the "sensitizing field." It is found that the sensibility of the retina varies over very wide limits depending upon the adaptation level, in fact due to this variable sensibility it is able to operate over a range of brightness from 1

to 100,000,000 (approximately). A complete expression of sensibility, therefore, requires measurement over the entire adaptation range, and the results are most conveniently expressed in graphic form as curves plotted with values of the various types of sensibility (threshold, contrast, and glare) as ordinates and the adaptation level as abscissae. These three sensibility curves are given in Fig. 1.

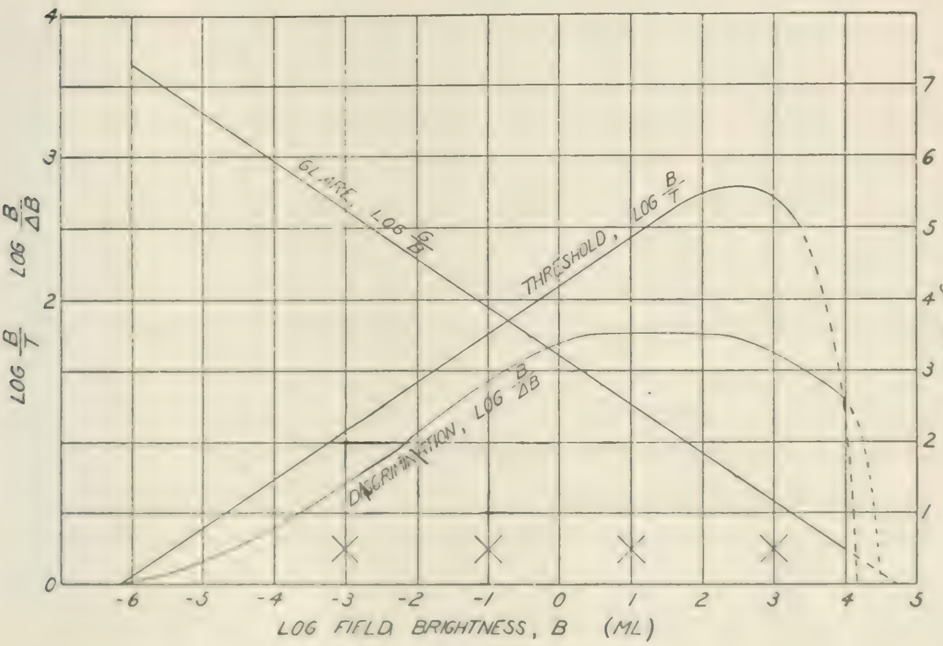

Fig. 1.—Sensibility curves.

Since the variation in value of adaptation level (field brightness) is enormous, it is convenient in plotting the curves to use the logarithms of these values. The ordinates are expressed in units appropriate to the various types of sensibility. For any specified adapation level it is now possible to read from the curves the brightness which is just uncomfortable (producing glare), the least perceptible difference in brightness (contrast) and the least perceptible brightness (threshold). Applying this to the case of an observer in a motion picture theater, we are able if his adaptation level is known, to find to what extent any area may be illuminated without producing glare, to compute the amount of general illumination which may be tolerated on the screen without producing a perceptible degradation of contrast, or to specify the maximum of brightness difference in the field of vision if undue eye fatigue is to be avoided.

In order to make such useful application of the fundamental data contained in the sensibility curves, it is, however, necessary to know the adaptation level of the observer under the particular conditions considered. Unfortunately the data necessary for this are not at present available. It will be recalled that the "adaptation level" is defined as specified by the brightness of a uniformly illuminated field filling the entire field of vision, and the retinal sensibilities were determined under such conditions. Now it is probable that the brightness of the foveal image is the most important factor in fixing the adaptation level of the retina, but undoubtedly the brightness of the images outside of the fovea has some influence. In the case of a person watching a motion picture, the picture itself usually occupies but a relatively small portion of the visual field, and in case the surrounding areas are very low in brightness his adaptation level will probably be somewhat lower than indicated by the average picture brightness. The effective application of the sensibility data, therefore, depends upon a reliable determination of the adaptation level under practical working conditions in the motion picture theater. An instrument is at present being developed with which the adaptation level of the retina when stimulated by non-uniform fields may be measused. It is hoped when such measurements are available that the application of the sensibility data will lend additional support to the conclusions reached in the experimental work to be described in the following pages.

In order to make an actual determination of the maximum general illumination permissible, an experimental lighting system was installed in the projection room in the research laboratory. In designing this system an attempt was made to obtain the maximum average illumination on the table plane (horizontal surface 30 in. above the floor) with a minimum of illumination on the projection screen, and further to distribute the light so that no area either of wall, ceiling, or lighting fixture should be sufficiently bright to cause glare or appreciable increase in the adaptation level of the observer.

In Fig. 2 is shown a side elevation of the room with the locations of the various elements of interest in this problem and the dimensions of importance. In Fig. 3 is given a plan view showing

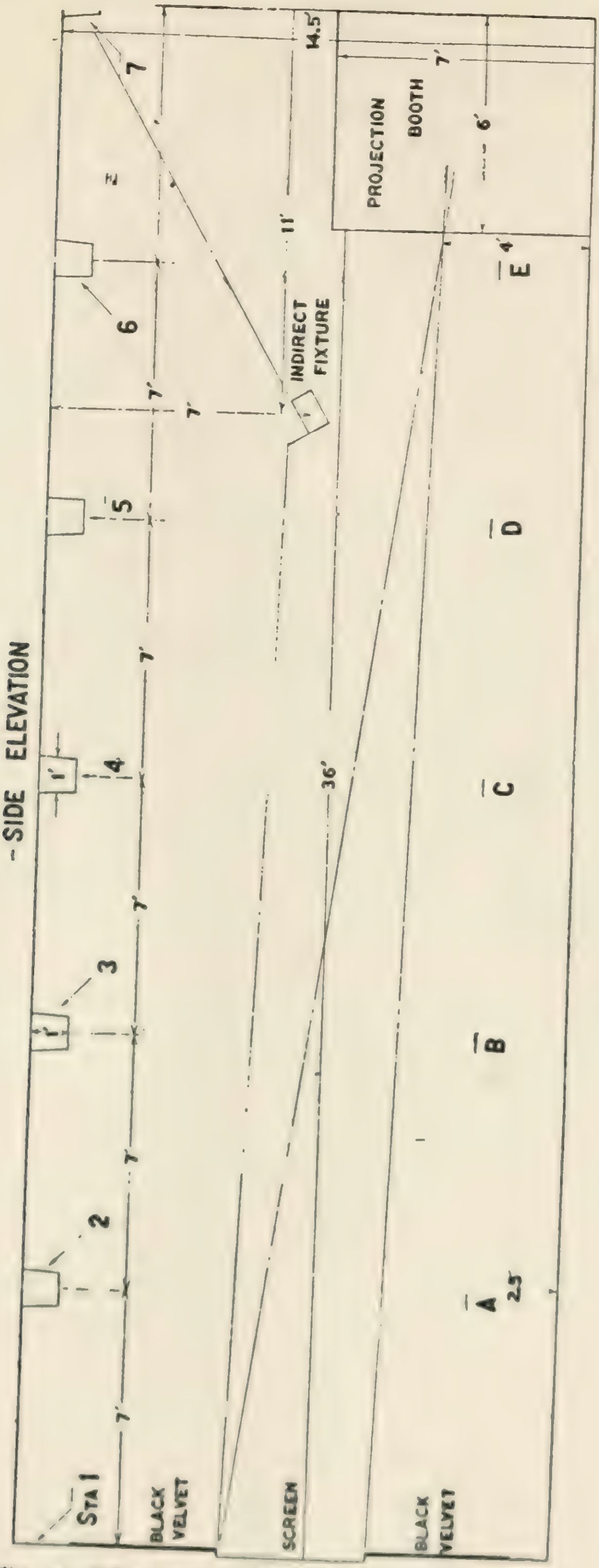

Fig. 2.—Side elevation of motion picture theater.

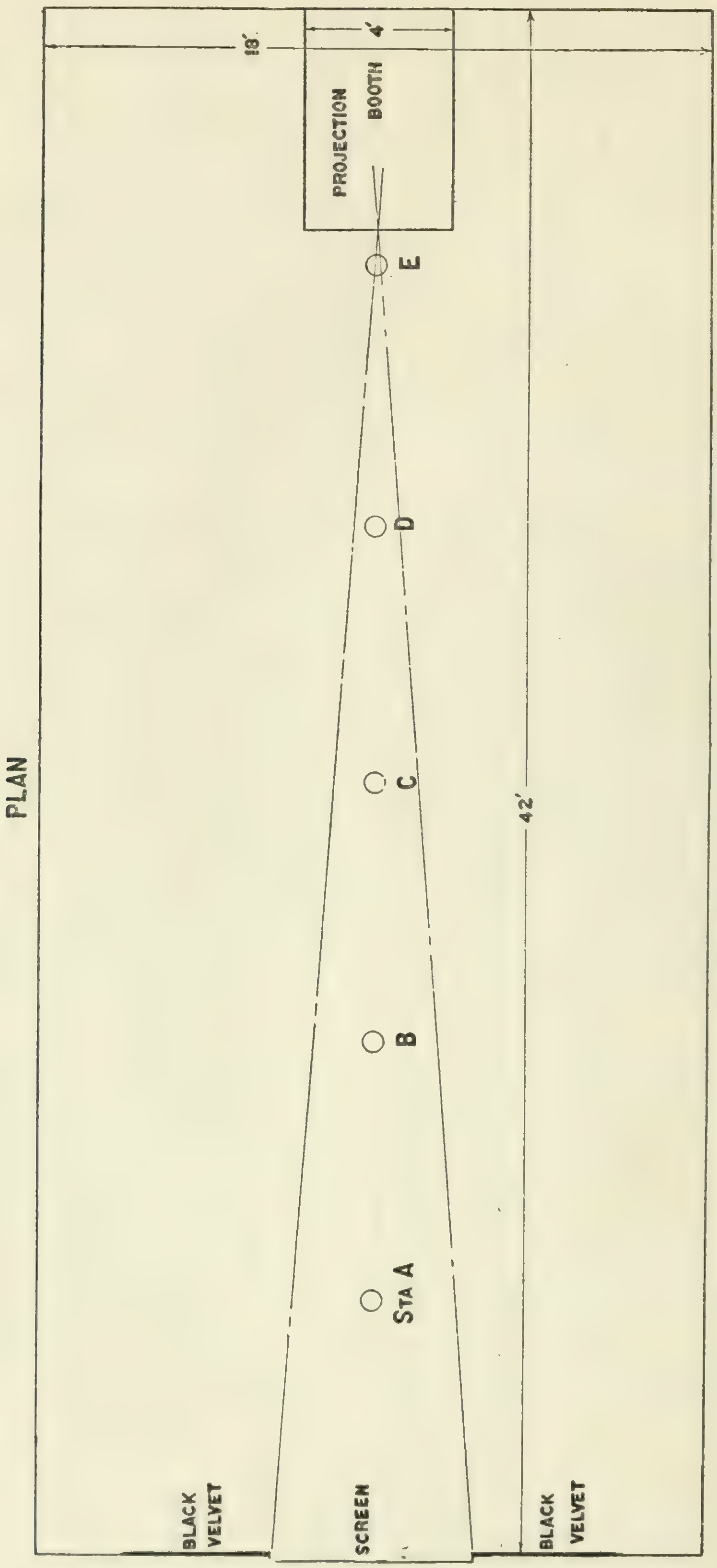

Fig. 3.—General plan of motion picture theater.

the position of the stations on the table plane at which measurements of illumination were made. The ceiling of this room is painted white, while the walls are a medium tone of buff. The projection screen is of the metallic type (Gaumont), having a high reflecting power for points on and near the axis, but falling off rapidly for angles greater than 15° from the axis.

The lighting fixture used was constructed by mounting six 10x 12-in. darkroom ceiling lamps on a light wooden frame work. In order that the position of this fixture could be adjusted to give various distributions of the light, it was suspended as shown in Fig. 4.

The vertical members *AA* carry the horizontal member *B*, which is a cylindrical metal rod about 21 ft. long. One of these fixtures is mounted near each side of the room, and parallel to each other. Upon these horizontal ways operate the sliding carriages *C*. Over small pulleys attached to this carriage the sash cords *FF* operate and suspend the lighting fixture as shown. By means of these adjustments it is possible to adjust the position of the lighting fixtures to any desired distance from the ceiling, to vary its distance from the projection screen by a considerable amount and further to vary the inclination at which the fixture hangs thus controlling to a great extent the distribution of the light from the fixture.

Complete diffusion of the light from the incandescent lamps mounted in the fixture was obtained by inserting a sheet of 10x12 in. opal glass in the position provided for the safe light fixture. In the projection booth is situated a projection machine of the ordinary type. An arc current of 25 amperes was used throughout the tests recorded in this report. With this current the screen brightness as measured with the machine running but without a picture in position was found to be approximately 20 foot-candles. This measurement was made from a point very near to the axis of projection and due to the character of the screen was much higher than the brightness measurement made from points a few degrees from the axis. From measurements made previously in several of the motion picture theaters in Rochester, an average value of screen brightness under similar conditions was found to be approximately 15 millilamberts. The screen brightness used in

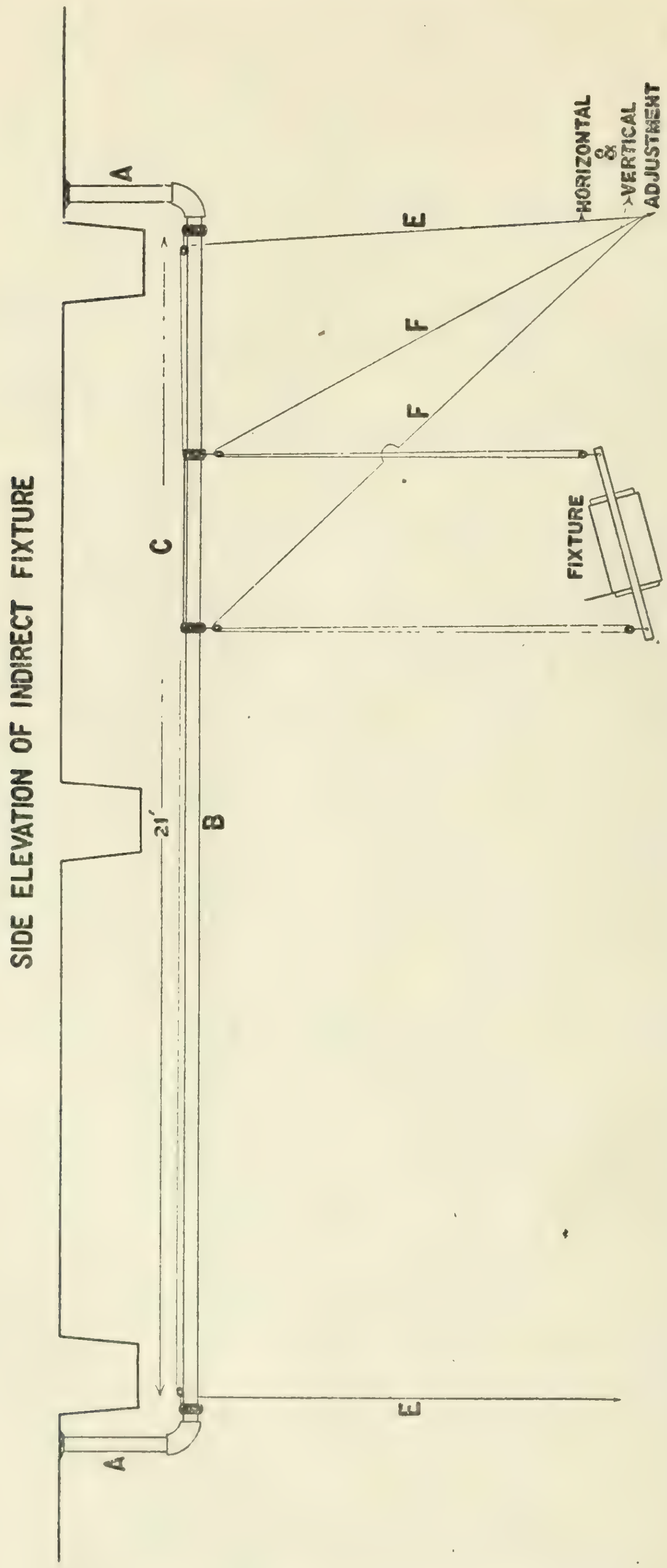

Fig. 4.—Method of suspending the lighting fixture.

these experiments therefore is somewhat higher than is ordinarily met with in practice.

The lighting fixtures having been installed, the procedure followed was to determine by trial and error the maximum amount of light which it was possible to use without causing an appreciable loss of quality in the picture. After several preliminary trials it was decided that the best result was obtained by placing 60-watt lamps in the four central elements of the fixture and 40-watt lamps in each of the end boxes, the entire 10x12-in. surface of the diffusing glass being uncovered and used as effective source area. The position of the fixture which was found to give a very satisfactory distribution of the light was as indicated in Fig. 5. This position was approximately 5 ft. from the ceiling and 11 ft. from the rear wall of the room, and with the fixture inclined forward so as to give an evenly graduated distribution of the light on the ceiling. It was found necessary in order to prevent excessive illumination of the screen by the light from the fixture to place a card-board screen along the front of the frame carrying the safelight fixtures. This was of such dimensions that no direct light from the opal glass was permitted to fall upon the projection screen, and served also to reflect some of the light backward so that the ceiling brightness at the rear of the room was brought up to a value more nearly equal to that of the brightness of the ceiling directly above the fixture.

This arrangement having been reached and considered satisfactory several observers experienced in the judgment of photographic quality were asked to express opinions as to whether or not the quality of the projected picture was seriously affected by the presence of this general room illumination. These observers were unanimous in the decision that not only was the photographic quality of the projected picture fully as satisfactory, but that the effect was more pleasing and resulted in much greater visual comfort. By observing the screen with the eye so shielded that nothing but the picture could be seen, the ceiling light was alternately turned off and on and the effect upon the quality of the pictures observed. Under such conditions it is possible to detect a slight veiling of the deeper shadows when the room illumination is being used, but it should be noted that this condition of observation does not permit the increased room illumination

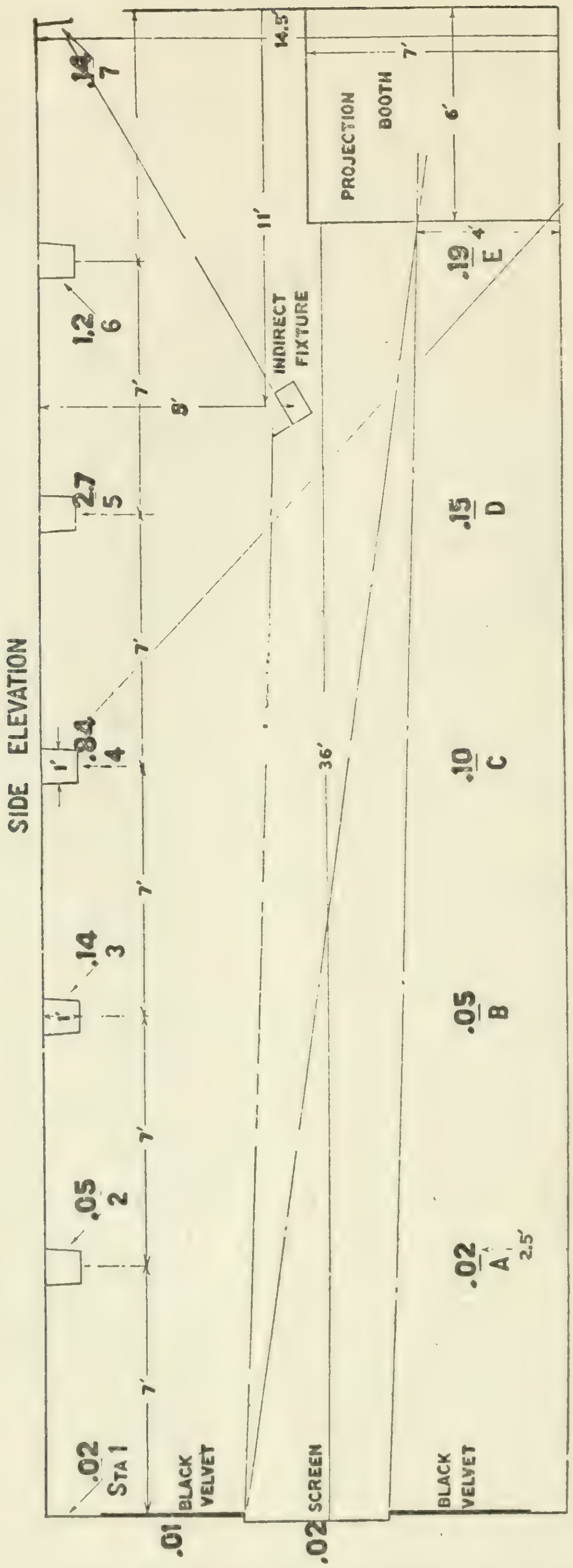

Fig. 5.—Position of fixture giving satisfactory distribution.

to act in the normal way upon the retina and thus raise the adaptation level. The increase in the value of adaptation level which under normal conditions accompanies the increase in the general room illumination under such conditions is therefore prevented from compensating for the objective loss of contrast due to the presence of the veiling glare incident upon the projection screen when the illumination levels of the room are high.

The veiling illumination falling upon the screen due to the general illumination in the room is sufficient to cause an easily measurable decrease in the actual objective contrast of the picture. The picture observed in the normal manner, however, that is, with the eyes not shielded so as to prevent the action of the room illumination on the peripheral region of the retina, appeared to be of practically the same contrast as when the room illumination was not used. The explanation of why the actual decrease in objective contrast produces such a small apparent effect is of fundamental importance; as mentioned previously it is due to the fact that the contrast sensibility of the retina rises with increase in the value of the adaptation level. The presence of the general room illumination is responsible for a rise in the adaptation level of the observer and the corresponding increase in contrast sensibility permits the perception of smaller brightness differences.

On the whole this arrangement was considered very satisfactory by all those observing. One point of interest noted was that much less visual discomfort resulted when the screen brightness was suddenly changed by the appearance of the title region of the film, and further that a slight residual flicker due to lack of precise shutter adjustment was less noticeable. In fact much less general eye fatigue resulted when the room light was on than when it was turned off.

In order then that a permanent record of the quantity and distribution of illumination used might be made, a series of brightness and illumination measurements were made. The points at which measurements were made are indicated in Fig. 2. The stations *A*, *B*, *C*, *D*, and *E* represent points on the table plane, that is, 30 in. from the floor, while the stations 1, 2, 3, 4, 5, 6 and 7 are situated at various points on the ceiling as indicated by the arrows and represent the points of maximum brightness as seen

by an observer situated at a point near station *D*. All values of brightness are expressed in millilamberts (ml.) and those of illumination in foot-candles (f. c.). In order that a complete analysis of the distribution of the light might be made, sets of measurements were made under four conditions of illumination, the data obtained being classified according to the following system.

Group I. Room illumination only.

Group II. Room illumination. 25 ampere arc in projecting machine. Machine running but with no picture.

Group III. The 25 ampere arc in projecting machine. Machine running.

Group IV. Room illumination. 25 ampere arc in projecting machine. Normal positive film in machine running.

The measurements obtained under I indicate the intensity and distribution of the light from the installed fixture. The data in III represent the intensities and distribution of the light reflected from the screen when the arc is operating, but with no picture in the machine. The data in IV are of greatest interest as they represent the distribution and intensity of the illumination under actual operating conditions, the sources of light being both the installed fixture and the light reflected from the projection screen. The data in II were recorded as being of interest in indicating the difference between the illumination with and without a picture in the projecting machine.

The measurements having been completed with this arrangement of the lighting fixture, it was decided to make a second adjustment and to repeat the measurements with slightly changed conditions. The distance between the fixture and ceiling was increased to 7 ft., and the inclination changed somewhat so that while the projection screen was protected from direct light a higher ceiling brightness near the front of the room was obtained. In the opinion of the same group of experienced observers, this second arrangement of the illumination was quite as satisfactory from the standpoint of photographic quality in the projected picture as the first arrangement. From the standpoint of the room illumination the arrangement was somewhat more satisfactory owing to the fact that a more uniform distribution of

brightness over the ceiling and a slightly higher illumination level near the front of the room was obtained. The photometric measurements were then repeated from the same set of groupings as employed previously. The data on the two arrangements of the lighting system are recorded in Table I. A detailed consideration of this table will not be given at this time.

TABLE.

	Ceiling brightness							Illumination on table plane					Screen and frame	
	1	2	3	4	5	6	7	A	B	C	D	E	S	F
I. A	.02	.05	.14	.84	2.7	1.2	1.4	.02	.05	.10	.15	.19	.02	.01
II. A	.03	.07	.14	.84	2.6	1.3	.18	.15	.09	.15	.15	.17	20.00	.03
III. A	.03	.03	.02	.02	.03	.06	.05	.10	.05	.03	.03	.03	20.00	.02
IV. A	.02	.04	.14	.84	2.6	1.3	.15	.04	.04	.13	.15	.19	10.00	.02
I. B	.04	.12	.28	.95	1.9	.84	.15	.03	.07	.17	.21	.17	.04	.02
II. B	.04	.12	.37	1.05	2.2	.95	.16	.13	.10	.15	.22	.20	20.00	.04
III. B	.03	.03	.02	.02	.03	.06	.05	.10	.05	.03	.02	.02	20.00	0.2
IV. B	.04	.12	.29	.95	1.8	.84	.16	.06	.07	.16	.19	.16	10.00	.03

Group I.—Room illumination only.

Group II.—Room illumination. 25 ampere arc in projecting machine. Machine running but with no picture.

Group III.—The 25 ampere arc in projecting machine. Machine running.

Group IV.—Room illumination. 25 ampere arc in projecting machine. Normal positive film in machine running.

In order to present these data in more graphic form, the values of brightness illumination are written in on the proper points on the prints showing the side elevation of the room, and a brief consideration of these will now be taken up. In Fig. 5 is shown the distribution of illumination due to the installed fixture in the first position found satisfactory. The position and inclination of the fixture are indicated approximately in the figure. It will be noted that the highest ceiling brightness occurs at Station 5 where a value of 2.7 ml. was found, the brightness decreases in both directions from this maximum, being relatively low on the ceiling near the projection screen. It will be noted also that the illumination on the table plane decreases in a fairly regular manner from the rear to the front of the room, the maximum value being 0.19 f. c. at Station *E* and 0.02 f. c. at Station *A*. In Fig. 6 is shown the distribution of illumination under actual operating conditions, a picture of normal density being projected with the room illumi-

nation as indicated in Fig. 5. It will be noted that due to the light reflected from the projection screen the values of illumination near the front of the room are somewhat higher than under the conditions represented in Fig. 5.

In Fig. 7 are given the data obtained with the second arrangement of the fixture, and it will be noted that the maximum ceiling brightness has been lowered somewhat while higher brightnesses are found near the front of the room, thus a more even distribution of ceiling brightness is obtained with this arrangement. The illumination on the table plane is also somewhat higher and more evenly distributed. In Fig. 8 the data obtained with the second arrangement being used under actual working conditions are shown. It will be noted that the illumination on the table plane now varies from a maximum of 0.19 at Station *D* to a minimum of 0.06 at Station *A*. Both of the arrangements specified by the values in Figs. 6 to 8 were found to be entirely satisfactory from the standpoint of picture quality, the second arrangement providing better general room illumination. With this illumination it is quite possible after becoming accommodated to the existing brightness level to read with comfort ordinary newspaper print and furthermore the length of time required for accommodation is very short. For instance, an observer entering a room with his eyes adapted to full exterior daylight levels can see immediately all details of furniture in the room, and a period of not more than 1 or 2 minutes is necessary for adaptation sufficient to read with ease ordinary printed material.

The details of another installation of somewhat different type but involving the use of the same fundamental principles are shown in Figs. 9 and 10. This is a room used for the exhibition of motion pictures, and while it is not of dimensions comparable with commercial motion picture houses, it serves to illustrate another way in which a satisfactory distribution of light may be obtained. The fixture providing the room illumination consists of a trough that extends across the entire width of the room. This is mounted in the position as indicated by the word "fixture," on the rear wall of the room and just above the projection port. The diagram shows a cross section of this fixture while the circle inside indicates the position of the lamps which are 25 watt, full frost spherical bulbs. Sixteen lamps are used, assembled on two

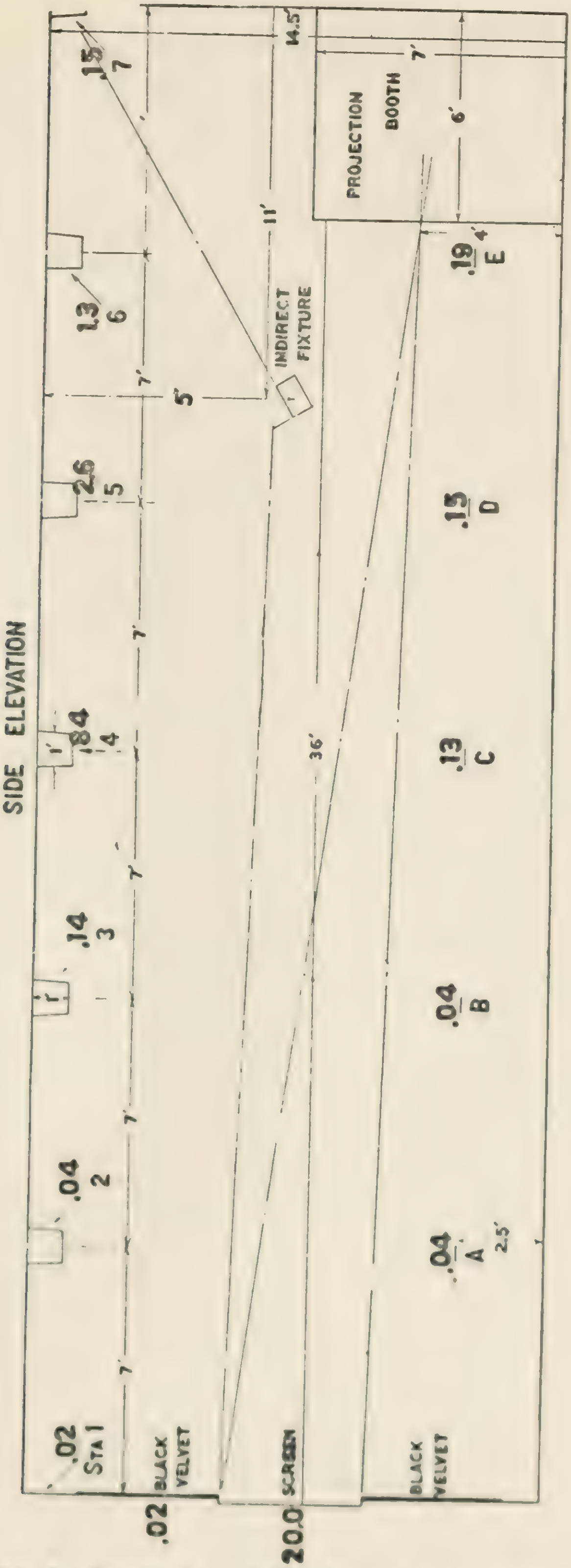

Fig. 6.—Distribution of illumination under operating conditions. (Group IV A.)

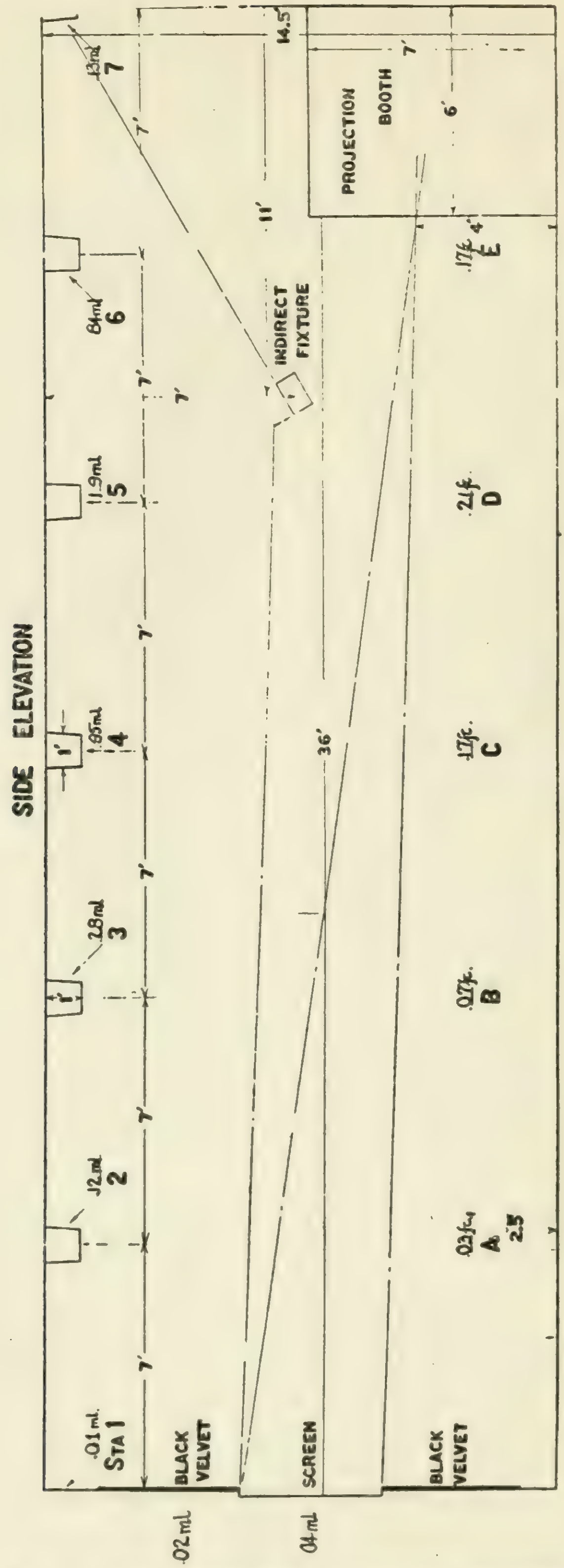

Fig. 7.—Data obtained with the second arrangement of the lighting fixture. (Group I-B.)

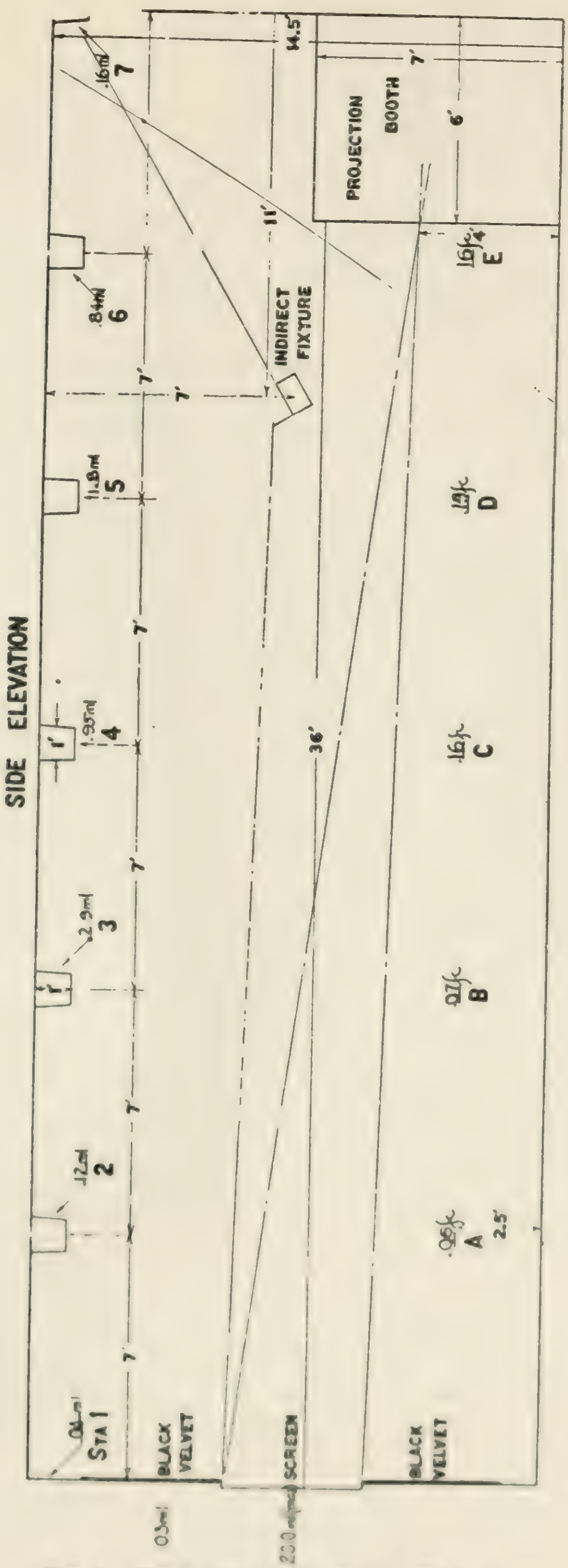

Fig. 8.—Data obtained in Group IV-B.

circuits so that eight or sixteen may be used as desired. The walls of this room are painted dark gray while the ceiling is white. The projection screen in this case is approximately 10x12 ft., being of white plaster from which the light reflected is almost completely diffused. With an arc current of 40 amperes and the machine running without film, the screen brightness was approximately 5 ml. and was practically constant for all angles of observation. Fig. 9 indicates the distribution of illumination and ceiling brightness with the room lamps alone, while Fig. 10 indicates conditions existing when a picture of normal density is being projected. Due to the fact that the lower edge of the screen is only about 15 in. from the floor level, it is impossible to seat observers nearer to the screen than the point indicated by *P* in each diagram. It was only necessary therefore in this case to provide adequate illumination in the region between *P* and the rear of the room. It will be noted that in this region the illumination on the table plane varies from 0.20 f. c. to 0.04 f. c., while the maximum ceiling brightness is 2.0 ml. at a point midway between the rear of the room and the first beam. All values designated at Stations 1 to 7 inclusive are in millilamberts while those at Stations *A* to *E* are values of illumination in foot-candles. The screen brightness with the room lamps alone is 0.007 ml. This illumination is very satisfactory, the picture quality being in no way degraded by its use. The bottom of the interior of the fixture is painted black so as to prevent an excessive ceiling brightness immediately above the fixture while the rear of the interior is painted white in order that the brightness of the ceiling at points farther forward in the room may be enhanced. The lamp bulbs used in this case were dipped in a light yellow lacquer, thus producing a softer and more pleasing effect than when the undipped bulbs were used.

The general conclusions to be drawn from these experiments are that a relatively large amount of general illumination may exist in motion picture theaters without appreciably affecting the quality of the projected picture provided that this illumination is properly distributed.

In Fig. 11 is shown a possible arrangement of the lighting system which would give a highly satisfactory theater illumination.

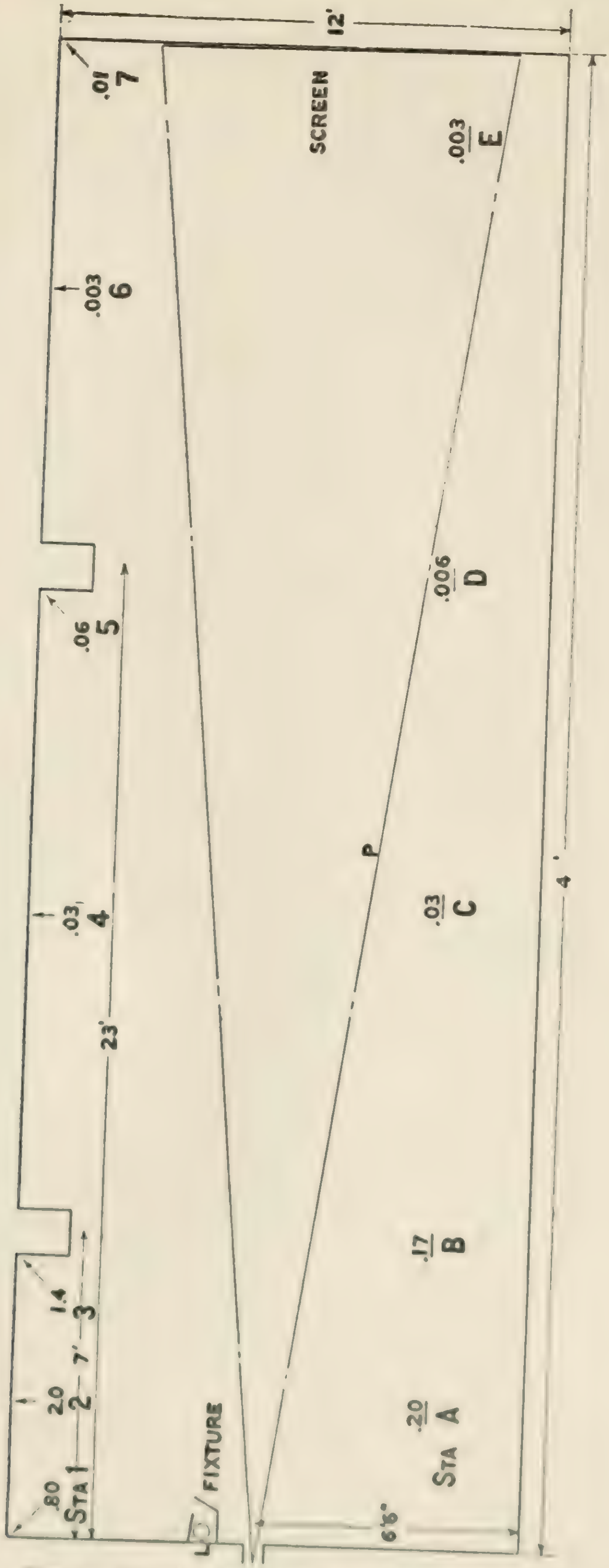

Fig. 9.—Illumination from room lamps alone.

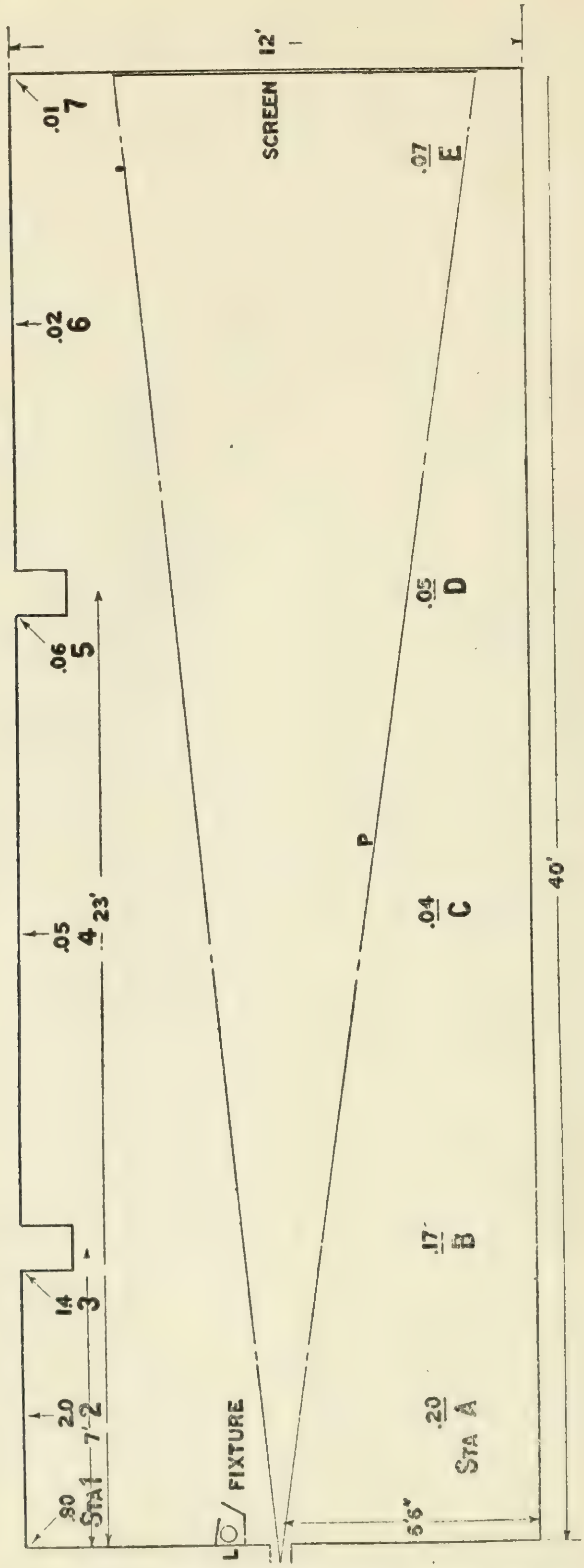

Fig. 10.—Illumination from room lamps and the picture screen.

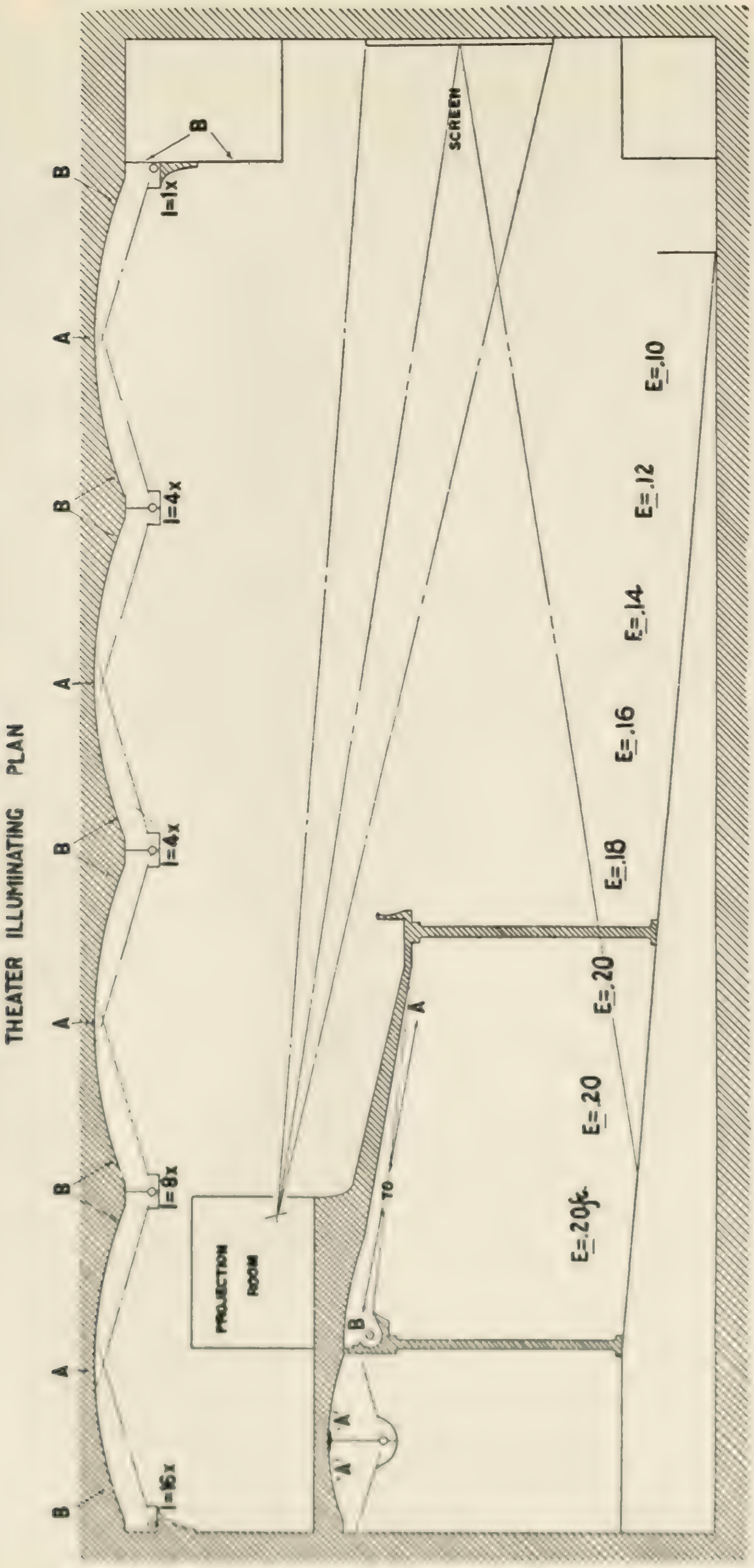

Fig. 11.—Proposed method of lighting a motion picture theater.

This plan is presented as illustrative of one way of handling the problem and undoubtedly many others may be worked out.

The ceiling which consists of four arches or concavely curved surfaces is illuminated by lamps inclosed in the fixtures as indicated, the intensity of the various lamps being arranged roughly as indicated by the numbers $i = 1x$, $i = 4x$, etc. This would result in a relatively high ceiling brightness at the rear of the theater and a relatively low value at the front. Since the lamps themselves must be placed comparatively close to the ceiling, it would be necessary in order to obtain an approximately uniformly graded ceiling brightness to arrange the decorative scheme applied to the ceiling so that the region marked B would have a relatively low reflecting power, while those marked A, on the other hand, would have a very high reflecting power. While the details of such a decorative system have not been worked out, it is undoubtedly possible to achieve. The lighting of the ceiling underneath the gallery is obtained from lamps at B and here again the ceiling reflecting power should vary from a low value at B to a high value at A.

The desirability of close co-operation between the lighting engineer and the designer of the decorative scheme to be applied to the interior of the theater should be emphasized. The proper adjustment of the reflecting power of various wall and ceiling elements is a powerful factor in the control of the brightness of such surfaces, and considerable judgment and skill in the adjustment of the decorative scheme to the lighting system may be necessary in order to prevent certain surfaces used very close to light sources from having excessive brightness.

From the results of the experiments in the projection room, it has been concluded that the illumination on the table plane at various points in the theater should be approximately as indicated by the values of E, and the number and size of the light units used should be so adjusted as to give the indicated values. While an approximate computation could be made indicating the number and size of units necessary, it would be quite impossible without detailed information of the dimensions of the room, the reflecting power of various surfaces, and the exact position of the lamps to make a definite estimate as to the total quantity of light flux necessary.

In Fig. 12 are shown three cross sectional diagrams illustrating the possibilities in beam design which would result in a satisfactory distribution of the light flux over the ceiling. These designs, of course, are only given as suggestions of what might be done in arranging an indirect system of illumination in order to conform with the conditions outlined previously in this report. The beam structure adopted in any particular case will be influenced to a great extent by the architectural style of the theater and the diagrams given serve only to suggest a method of concealing the lamp within the beam structure and at the same time obtaining the proper illumination of the ceiling.

It should be mentioned also that the illumination in the lobby and in the various vestibules and the extreme rear of the theater should be so arranged that a person entering the theater passes gradually from the illumination of the exterior to that of the body of the theater. That is, the transition from exterior brightness level to the interior brightness level should be made in a series of gradual steps rather than in a single abrupt step.

Turning to a consideration of the brightness of the frame surrounding the picture, it was found by experiment that raising the brightness of the frame to a value of approximately 0.02 ml. gave a much more pleasing effect than when the black velvet frame was used in which case the brightness was so low as to be beyond the limit of measurement with the instrument available. The contrast between the frame and the highlight of the projected picture which is estimated to have been about 1 to 10,000 in case of the black velvet frame was found to give rise to a certain feeling of visual fatigue and discomfort. By covering the velvet with a draping of white mill net the reflecting power was increased to such an extent that the contrast between the frame and picture was considerably reduced. It will be noted that the average screen brightness without any picture in the screen is found to be 20 ml. The average screen brightness with a normal film in position is probably of the order of 2 ml., while the maximum may be taken to be somewhere in the neighborhood of 10 ml. With a frame brightness of from 0.02 to 0.03 as indicated by the data, the maximum contrast between picture and frame is reduced to less than 1 to 1000 while the average contrast is approximately 1 to 100. Now the sensitometric data

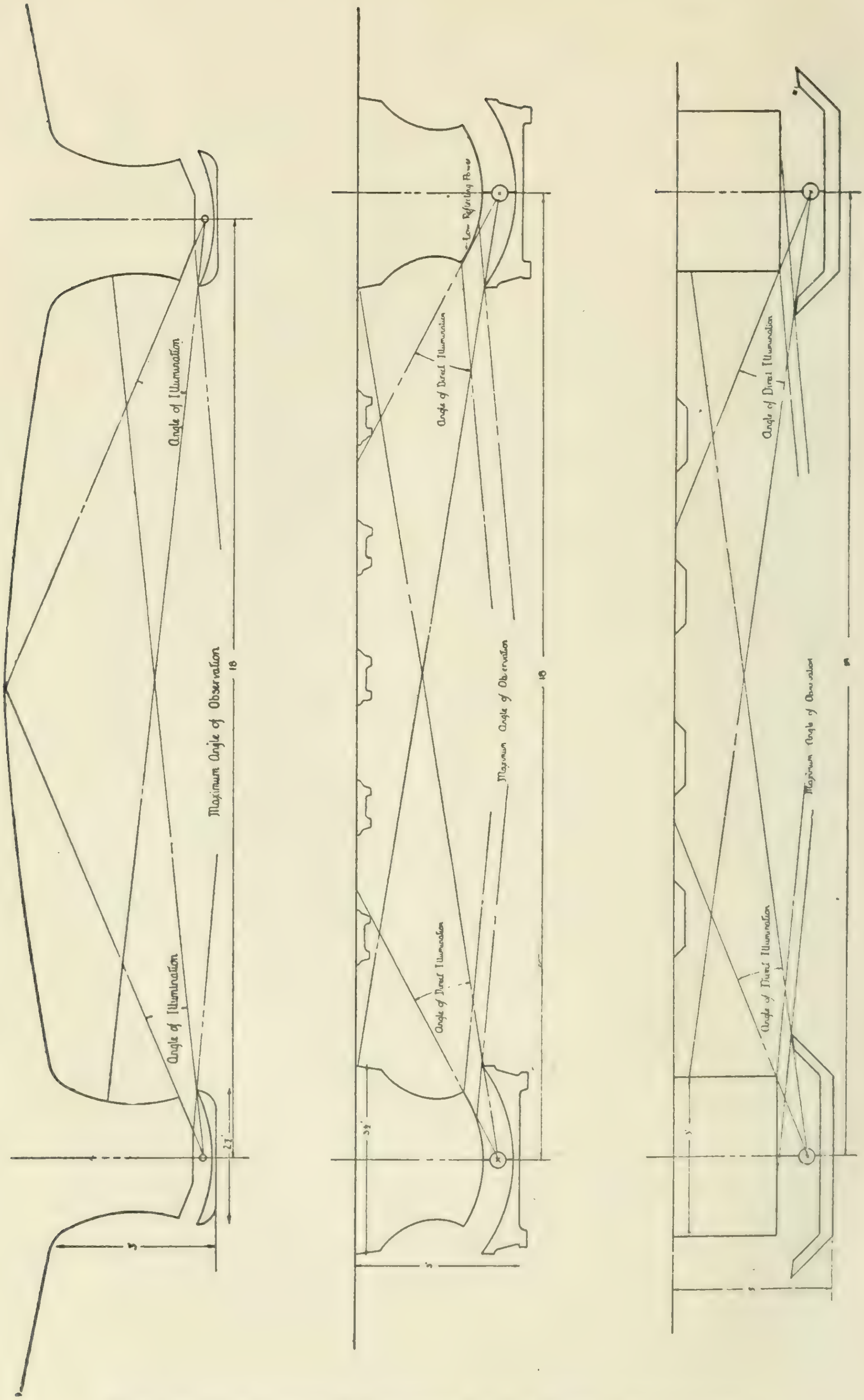

Fig. 12.—Cross sectional diagrams showing beam arrangements.

on glare indicate that with the eye adapted to ordinary daylight levels a contrast of over 1 to 100 results in glare or undue fatigue. However, with the eye adapted to lower levels, the allowable contrast increases to a considerable extent and if (See Fig. 1) we assume an adaptation level of 1 ml. the data indicate that contrast as great as 1 to 1000 may occur in the visual field without resulting in glare or undue visual discomfort. Contrast greater than this, however, should not be permitted. These results indicate that in general a black frame should not be used, but that a much more pleasing and less fatiguing arrangement will be obtained by the use of the frame of somewhat higher reflecting power.

CONCLUSIONS.

The general conclusions are, therefore, as follows:

It is quite possible to use a system of lighting in a motion picture theater which will result in illumination levels on the table plane much higher than those at present prevailing. The illumination may in fact be raised to such an extent that ordinary newspaper print can be read with ease by an observer adapted to the existing brightness levels. The presence of this increased illumination does not cause any appreciable degradation of quality in the projected picture. The accomplishment of such satisfactory results depends upon the proper distribution of the light.

While it is impossible to outline specific instructions for particular cases without detailed knowledge of such factors as dimensions and architectural details of the room, the reflecting power of the various ceiling and wall surfaces, and the position of the light fixtures, the following general principles may be outlined, it being understood that the numerical values are approximate and that some variation may be allowable depending upon the particular case.

(1) The illumination on the table plane should vary from 0.10 f. c. at the front of the theater to 0.20 f. c. at the rear.

(2) No area (outside of the projected picture) visible from any seat in the theater should have a brightness of more than 2.5 to 3.0 ml.

(3) The attainment of (1) without exceeding the values mentioned in (2) requires the use of very extended effective sources such as illuminated ceiling and walls and is best accomplished by the use of an indirect system of lighting.

(4) All light sources and fixtures such as diffusing globes and translucent glassware having a surface brightness of more than 2.5 to 3.0 apparent foot-candles should be entirely concealed from view.

(5) It should be noted that a sheet of white paper illuminated by a 25-watt lamp at a distance of 12 in. has an approximate brightness of 20 apparent foot-candles. A sheet of music, therefore, illuminated in this way, if visible, becomes a glare spot and may cause great discomfort to the audience. Arrangements should therefore be made which, while providing adequate illumination for the musicians in the orchestra, will prevent the illuminated music sheets from being visible to the audience.

(6) Considerable attention should be paid to the character and position of exit signs. While it is necessary to make such signs very conspicuous, this can be accomplished without making them so brilliant as to become disagreeable glare spots in the field of the observers' vision.

(7) The contrast between the highest light of the picture and the surrounding frame should be less than 1 to 1000 preferably less than 1 to 500. Black frames should, therefore, be avoided, one of a neutral gray being much preferable.

(8) Lighting of lobby, vestibules, etc., should be so arranged that the transition from the brightness level of the exterior to that of the interior or vice versa is accomplished by a series of small differences rather than by a single large one. Such arrangement will to a great extent eliminate the visual shock which accompanies a sudden change in the intensity of the visual stimulus.

(9) The use of a projection screen set well back on the stage and thus shielded to a great extent from the light reflected from ceiling and walls would probably permit the use of even greater room illumination than was used in these experiments.

In conclusion the author wishes to acknowledge his indebtedness to Dr. C. E. K. Mees for helpful suggestions throughout

the course of this work, and to Mr. Milton Fillius who ably assisted in the conduct of the investigation.

Research Laboratory,
Eastman Kodak Company,
July, 1920.

DISCUSSION.

H. P. GAGE: In Montreal this spring the material contained in this paper was presented before the Society of Motion Picture Engineers. It was with considerable astonishment that I listened to some of the comments made. It is pointed out here that it is possible to do what one would naturally assume was desirable to do, namely, to have a light of such intensity on the screen from the projection machine, with no light of damaging intensity falling on the screen from the general lighting system, and at the same time to provide a certain amount of light for the audience to see their seats. Curiously enough, however, the question was raised as to whether it was desirable to light the audience.

To the illuminating engineer this at first sight appears peculiar and yet the psychology of the situation was brought out by a practical man who had done a great deal of work in designing an illuminating installation in a theater which would probably produce approximately the results here described, but the result was not satisfactory. The reason is fairly obvious, considering for example the lighting of this room for people observing motion pictures.

With the room lamps in use in this hall we were able to see very nicely the lantern slides projected on the screen. There is not enough light on the screen to interfere with the definition of the lantern slides. If one of our friends came in from the outside, we were perfectly able to recognize him due to a skylight. If we wanted to read our papers, we were perfectly able to do so. Yet, if we were observing motion pictures, we would not care to see anybody in the audience or have our attention distracted from the pictures, and this point must be considered by the illuminating engineer before going too far in the lighting of the auditorium.

In certain installations made by practical men the point has been brought out, that they are getting away from the black border and are coming to the gray border around the picture as being less fatiguing to the eye.

F. E. CADY: The point raised by Dr. Gage regarding distraction is one I have often noticed when attending motion picture exhibitions, and it seems to me the question of glare in connection with contrast of surroundings, is not really so important as to eliminate or subdue bright objects which may intrude in the field of view, to which the eye tends to move or toward which it is attracted.

This undoubtedly is a question of eye fixation and I think that every one will recognize that if the point toward which he is looking is the only point in the field of view, which has any appreciable attraction, then there is no tendency for the eye to wander, and no effort is required to hold it toward the point at which he is looking. It seems to me this is of especial importance in connection with one of the points raised in the paper, namely, the illumination of the music of the musicians. There is hardly a case in the moving picture theaters I have visited where there was not a tendency of the eye to wander down to the musicians. It is not a question of glare, it is simply a question of distraction, and my own experience when confronted with such distractions is that more comfort is obtained if I hold before my eye a sheet of paper or something to cut off everything below the level of the picture. Then there is no eye fatigue, and no tendency for the eye to wander from that which is being observed.

It also seems important to give more attention to the exit lamps. Often these exits are indicated by red lamps of considerable candlepower, and it seems that the attention of the authorities could well be called to the desirable results of marking the position of the exits, by lamps of much less candle-power, and much more diffused, so the effect would not be one of distraction.

NORMAN MACBETH: One question I want to ask Mr. Jones. Regarding the determination of the adaptation level, he says: "For any specified adaptation level it is now possible to read from the curves the brightness that is just uncomfortable (producing glare), the least perceptible difference in brightness (contrast) and the least perceptible brightness (threshold)."

How much below the "uncomfortable curve" is comfort found? In the theater described, the bright field of the screen shown

which was practically the full end wall, how would you decide your adaptation level? How would you get it in a theater where the screen was probably 25 per cent. of the end wall?

I would like to know if there are any figures. It appears to me from scanning the paper that the brightness of the screen was measured with the machine running without a picture. What would be the probable average reduction of the screen when projecting a picture?

On the sheet music, I understand that there is a great deal of difficulty also with the eyes of the musicians and whether that is due to the bright sheet music with the surrounding field dark or their following the picture to note certain parts of it, especially in the smaller theaters, and the change from the sheet music to the screen provides too great a contrast. I understand there is a great deal of eye discomfort suffered by these musicians. If the music were printed with white characters on black paper, that would perhaps help the audience, although it would be a rather expensive proposition. Would it help the musicians, or would the eye conditions be worse?

F. C. CALDWELL: Recently at a moving picture theater I found the room lighted with a deep blue light from blue lamps. I wonder if any investigations have been made on the effect of color on this problem.

BASSETT JONES: I have tried using blue light in the musicians' stands, with excellent success. The only difficulty is that if the house light goes out suddenly the musicians have to adapt their eyes to a color change. After that they are able to see clearly and the lighted music does not disturb the audience.

L. A. JONES: In regard to the desirability of providing more adequate illumination in the interior of motion picture theaters, it seems to me there can be no question. I think the average patron would much prefer to go into a theater where he is able to find his way to a seat, and to be sure that the seat chosen is unoccupied. Some one has questioned the desirability of the observer being able to see his immediate surroundings on the

ground, I suppose, that such visibility will make it more difficult to keep the attention concentrated on the picture being shown. It strikes me that if people go to the theatre to see the picture this objection can have little weight, and undoubtedly it is desirable to provide sufficient illumination so that the management can adequately supervise the conduct of the individuals in the audience. Further, I think as the quality of the plays presented is improved that it may be highly desirable in many cases to provide the audience with programs for the reading of which much greater illumination will be necessary than is found in the average theater at the present time. I understand that it has been stated that the motion picture public prefer a dimly lighted theater, this being based on the fact that the attendance of a certain theater decreased subsequent to a considerable increase in the interior illumination. Personally, I have considerable doubt that any such consequence would follow in the case of our better class of motion picture theaters. However, as pointed out by Dr. Gage, the question is of considerable importance and care should be taken not to raise the illumination above the tolerable value.

In the determination of the glare curve, the brightness which was just uncomfortable was taken. It is assumed that the difference between the just uncomfortable and just comfortable condition is very small and hence the glare curve may for all practical purposes be taken as the boundary between just comfortable and just uncomfortable brightness levels.

In the experiments reported in this paper the screen used did not fill the entire field of vision, and moreover the screen was surrounded by a black velvet frame about 4 ft. wide. The retinal field conditions were therefore not similar to those under which the retinal sensitivity curves were determined, and, as stated in the text, it is impossible at the present time to interpret directly in practical terms this sensitometric data, since in practice we must deal with retinal fields which are not uniform in brightness.

As stated previously, work on this program is going forward and we hope in the near future to be able to make measurements of the adaptation level for non-uniform visual fields such as exist in practice.

In regard to the average density or transmission of a motion picture film, I think that a value of 10 per cent. is approximately correct. The high light regions rarely transmit more than 80 per cent. while those regions representing the deepest shadows probably transmit less than 1 per cent. The total transmission, of course, depends upon the subject, but I think that on the average a value of 10 per cent. would not be far wrong.

RECENT APPLICATIONS OF COLOR IN LIGHTING.*

BY AUGUSTUS D. CURTIS AND J. L. STAIR.

From a standpoint of strict utility, color could possibly be done away with, and from a like standpoint, music has no large place in the world, but the person is rare indeed upon whom the flaming gorgeous tints and colors of a sunset has no influence, and who would be just as well pleased with life if this garden of a world were inhabited by colorless birds, the fields deprived of their colorful verdure, or the hedges and gardens robbed of their infinite variety of tones.

Each of us has an "eye for color." The degree with which we perceive color and enjoy color contrasts differs widely with individuals. The normal man or woman can distinguish many shades of light and dark as well as a large number of different hues. Everything that we see is colored. It seems, after all, that color is here to charm the eye. We can not isolate ourselves from what has been called the "spell of color."

Sight is not the only one of the senses that is affected by color. All of the senses are directly or indirectly appealed to. The nature of the color governs the character of the sensations experienced by the individual. Each tint may have a marked influence upon the mental state and affects us pleasantly or otherwise.

It is the subtle colors that attract us most, not those of a pure or crude nature. Of course the trained artist can discern and enjoy an unusual number of contrasts of colors, whereas most of us have a limited "emotional vocabulary" as respects color.

It is encouraging to note, however, that with each successive lighting season there is a broader use made of color concepts by lighting men and a consequent enlarging of the sphere of color in the illumination of exteriors and interiors, resulting, we are confident, in a gradual development of color appreciation by the masses.

Many, many years ago, the development of the Chinese lantern was no doubt the result of the demand inherent in the human being for change and variety of color in lighting.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

The Hudson-Fulton celebration and the work done at the Panama Pacific Exposition mark high points in spectacular outdoor lighting, events that have given great impetus to this new art in illumination. In the Alleghany County Soldiers' Memorial, at Pittsburgh, installed some ten years ago, the colored illumination was treated as an integral part of the decorative features of the building.

The efforts of such men as Mr. M. Luckiesh, Mr. Claude Bragdon, Mr. W. A. D'A Ryan and others have been far reaching. Mr. Bragdon's presentation of the festival of "Song and Light" a few years ago in Central Park, New York, attracted a hundred thousand people, indicating that there is a positive response on the part of the public to artistic color effects in lighting.

No attempt will be made here to go into the physics of color, the psychology of color, color preference, or the theories of color vision. All of these subjects are admirably recorded in the TRANSACTIONS of the Illuminating Engineering Society, February 1918, in a "Symposium of Color."

MEDIUMS FOR COLOR LIGHTING.

The general application of color in lighting has been hampered from time to time because of the mediums with which we have had to work, colored fabrics, gelatin screens, dipped lamps and sheet glass have been fairly satisfactory in certain instances. However, in cases where the heat factor is large and comparatively great intensities are desired, the mediums mentioned will not wholly fulfill the requirements, because of fading and burning of the medium. Continuous service causes them to lose their character and efficiency.

Dipped or colored lamps are useful where the heat factor is not an important element. They do not even under seemingly favorable conditions entirely meet the need because of the expense of maintenance, replacements, or lack of facility for dipping of lamps, mixing of colors, or carrying of sufficient stocks of colors and sizes.

With gelatin a great variety of colors is available, and when the sheets are placed between wire screens to prevent wrinkling, they are found to be very desirable for many classes of color lighting

work, especially with lamps of mazda "B" class and low wattage mazda "C" lamps.

With the advent of the mazda "C" lamp came large wattage units burning at comparatively high temperatures. The heat generated further complicated the possibility of securing suitable color mediums for permanent installations. Because of lack of stability in color lighting effects and cost of replacements of the medium, a new type of color slide of special glass with the color incorporated in it has recently been standardized and seems to solve the difficult problems for a large class of installations.

It is thought that the production of these special color plates is a very important improvement and will be of interest to those who are concerned with color lighting. By the proper application of these plates, more rapid advancement in the new art of color in lighting will be possible without the handicap of fading out of the mediums.

To advance in any art, there must be examples presented for study and criticism. It is proposed, therefore, to describe some attempts to further the new art of color in illumination, indicating the manner in which the effects have been produced.

COLOR IN HOME LIGHTING.

The home of all classes of interiors affords the most interesting studies in lighting methods and effects. Here if anywhere we should have the melody of color, the language of harmony.

From the decorative aspect, the lighting of the home gives us the greatest opportunity for the exercising of ingenuity in producing unusual effects and for working out the individual tastes of the householder.

In the living room, for instance, the illumination must combine the requirements of beauty and utility. It must have practical lighting qualities and elasticity.

An example of a living room shown in Fig. 1 indicates the ideas of a particular householder in producing novel effects by careful placing of the lighting units. The lighting furniture in this case consists of two luminous bowl indirect lighting units suspended from the ceiling, two urn lighting units, two ornamental brackets, one indirect lighting portable lamp and one ornamental portable lamp. With these various units, several color lighting effects or hues are obtained in the room.

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Fig. 1.—Living room in which color lighting has been used with good effect.

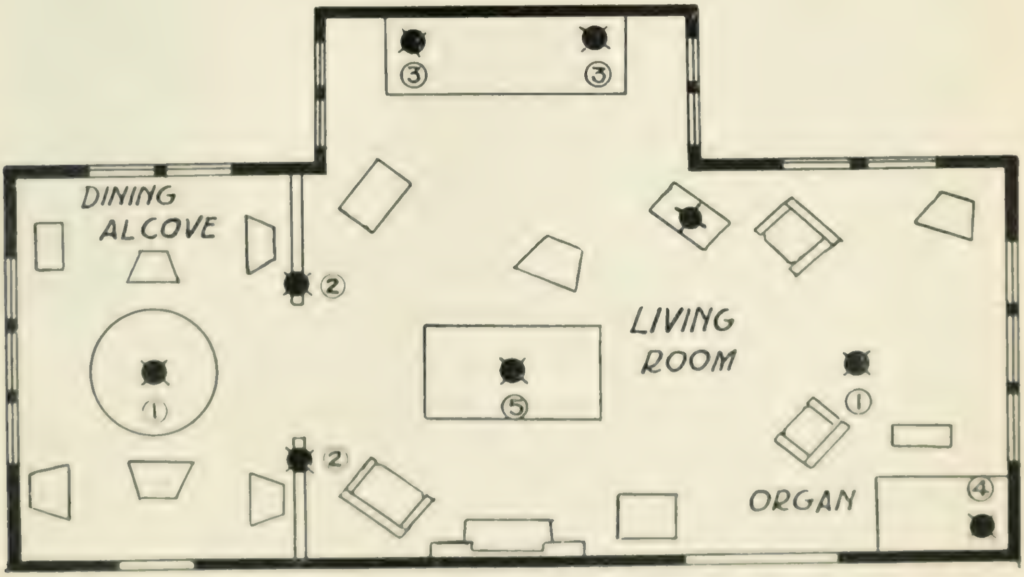

Fig. 2.—Plan of residence living room (18' x 35') illustrated in Fig. 1 showing disposition of lighting outlets.

Fig. 3.—Example of Sun Room where tinted illumination would be most appropriate and could be artistically employed.

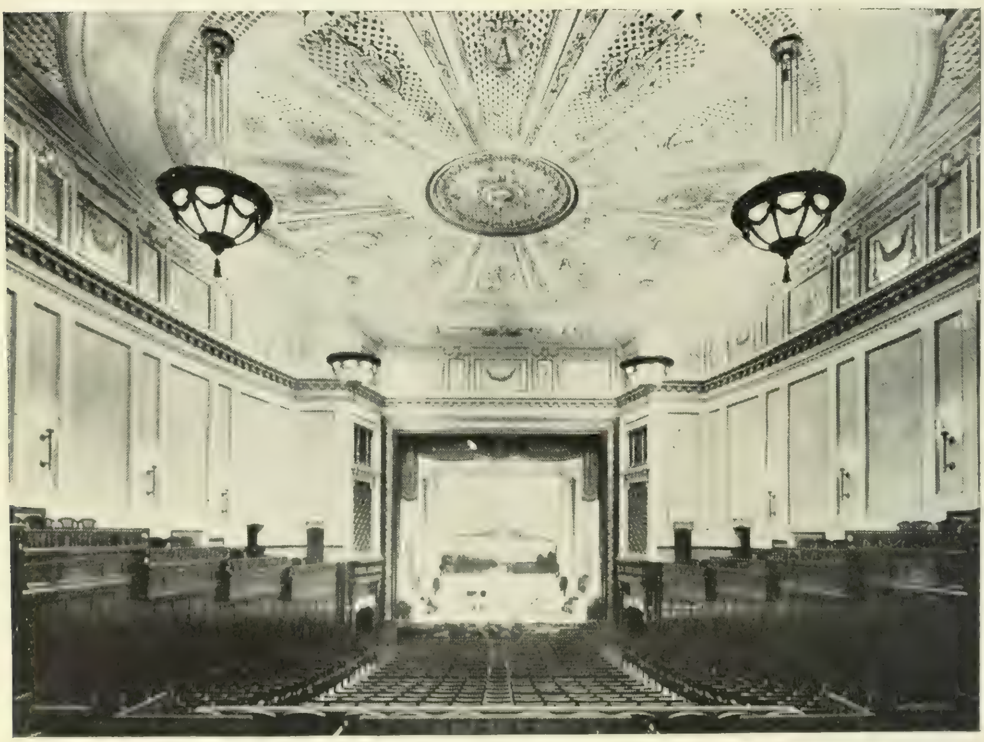

Fig. 4.—Auditorium of theatre, for which color changes were embodied in the lighting arrangements.

A very light green color is produced by means of a green gauze placed over the urn lamps at location No. 2 (see Fig. 2), and from the indirect bracket reflector placed behind the organ in location No. 4, also from the green dragon table lamp at location No. 5.

A warm amber color effect is obtained from the luminous bowl fixtures with the auxiliary lamp in use in the bowl at location No. 1, and from the auxiliary lamp behind the table lamp shade at No. 5, as well as from the two brackets at location No. 3. The colors of the silk shades at location No. 3 and location No. 5, harmonize with the color of the glass in the fixture at location No. 1.

Ordinary unfiltered light is obtained by using indirect lighting fixtures at locations Nos. 1 and 5. The fixtures at No. 1 are on three-way switches, thereby adding to the flexibility of the system and giving several intensities to the ordinary lighting. This arrangement facilitates the mixing of the colored lights with the white and assists in producing various gradations of tone.

The indirect portable lamp of the floor type or of the table type, such as used at location No. 5, equipped with changeable color screen over the upward reflector, affords a most effective means of obtaining color variations in the home. The lamp is easily moved about and the color screens readily shifted.

For festivals and special occasions, color is often made use of in decorative arrangements of the dining room. The months of the year, the days of the week, each have their emotional tone, which may be symbolized by color. St. Valentine's Day, Thanksgiving, St. Patrick's Day, Christmas, are some of the occasions that have already been placed in our color vocabulary.

A room of the type shown in Fig. 3 is an excellent example of an interior where tinted lighting would be most appropriate and could be very artistically employed. The question as to whether or not our artificial lighting should be the same color as daylight is still a debatable one. All the night lighting devices have produced a yellowish light. We have, therefore, been trained through the ages of the burning brand, candle, gas flame, and even the incandescent lamp, to use a yellowish color for artificial illumination. Warm yellow in the home suggests brightness and

effective lighting fixture without robbing it of its artistic character. The fixture may be retained in all its beauty and yet have the added qualities of being light-giving and glareless.

In one of the theatres of our experience, all of the principal lighting for the auditorium, with the exception of the under balcony section and for the proscenium arch, comes from a fixture of the type shown in Fig. 12. This fixture has a capacity of about 13,500 watts, measures 9 ft. in diameter and 17 ft. in height. The wiring is arranged in eighteen circuits and serves 482 individual lighting units consisting of indirect reflecting devices with color attachments, candles around the periphery of the chandelier and lamps in the interior of the fixture body.

The combining of the artist's skill and the practical application of illumination in a fixture of this character is somewhat of a departure, and has resulted in a lighting unit that has all the beauty of the old time crystal chandelier to which is added infinite variety in color effects by light emanating from within the fixture as well as projected upon its exterior.

STAGE LIGHTING.

Six years ago at the close of the season, David Belasco remodelled his theatre in New York. Among other things, the stage lighting equipment was entirely redesigned and a method devised that was a radical departure from the ordinary methods for stage lighting. It was our opportunity and pleasure to co-operate with Mr. Belasco and Mr. Hartman in this work.

The results produced by the new scheme were so different and so far in advance of the ordinary effects, and at such a great saving for electrical current that other producers have followed Mr. Belasco's lead by giving more careful thought to the artistic and economical lighting of the stage.

The "Boomerang" was the first play to be presented with the new lighting system. The light was thrown upon the stage from strips similar to that shown in Fig. 13. With the new method each lamp has its own reflector, thus making possible the most effective use of the light delivered from the lamp. The losses in control and quantity of light with the old types of borders was enormous. This new method has consideration for efficiency in stage lighting. It is scientifically based upon the fundamental principles of light control and its rapid adoption indicates that

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Fig. 5a.—Sketch of fixture used in lighting Theatre shown in Fig. 4.

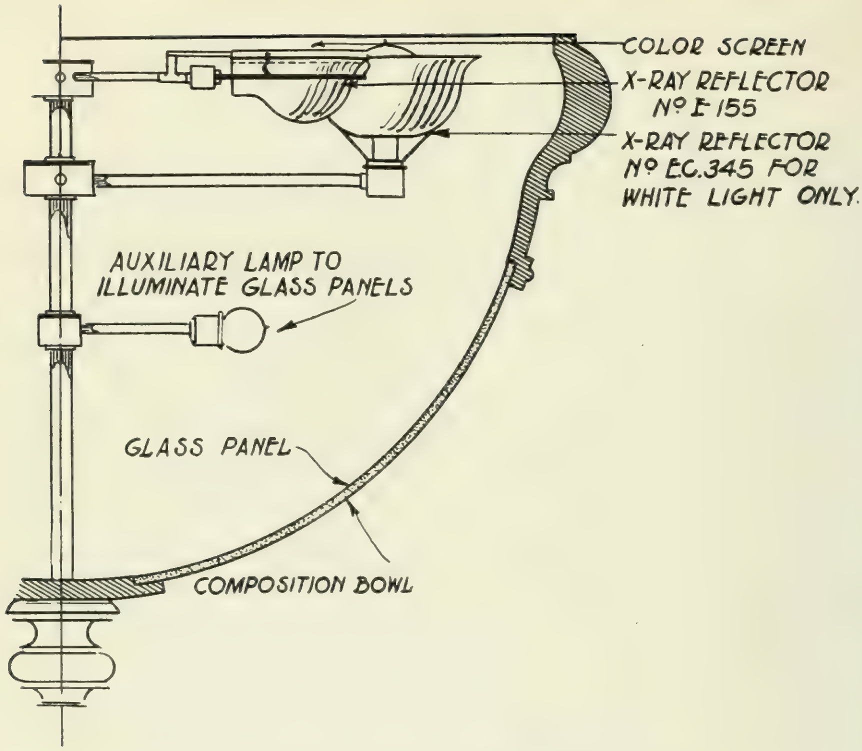

Fig. 5b.—Sectional view of theater lighting fixture.

Fig. 6.—Lobby of theatre showing use of decorative lamps.

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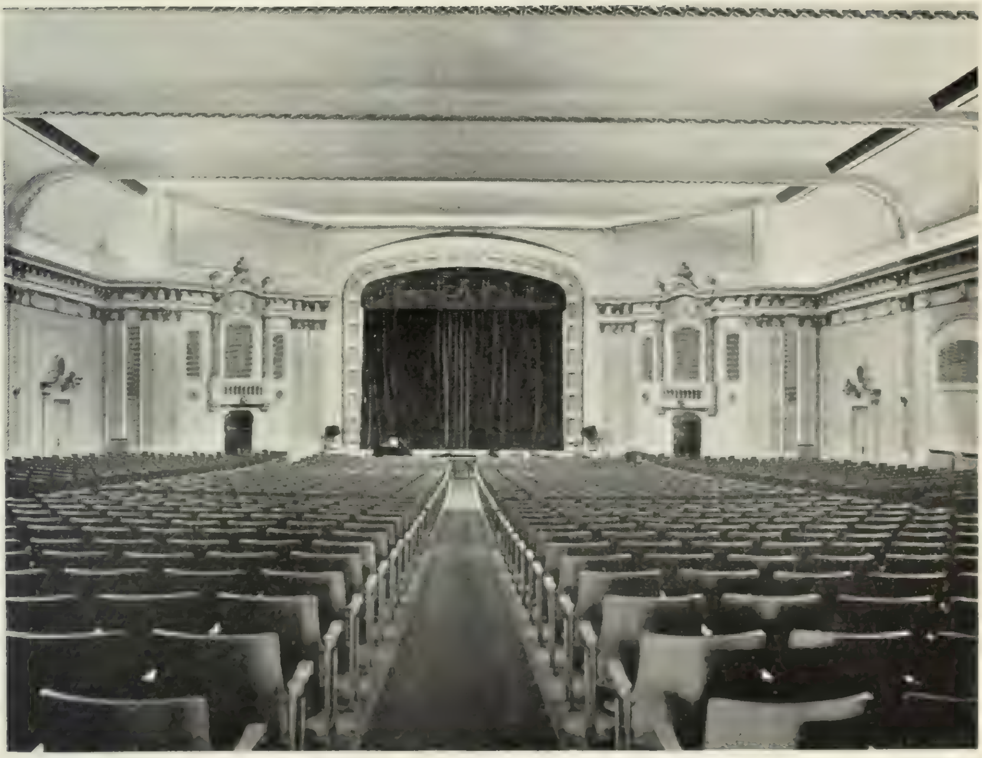

Fig. 7. Theatre with cove lighting and architectural feature favorable to use of colored illumination.

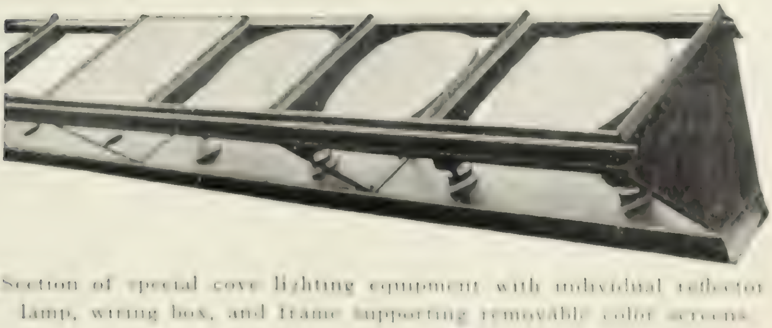

Fig. 8.—Section of special cove lighting equipment with individual reflector for each lamp, wiring box, and frame supporting removable color screens.

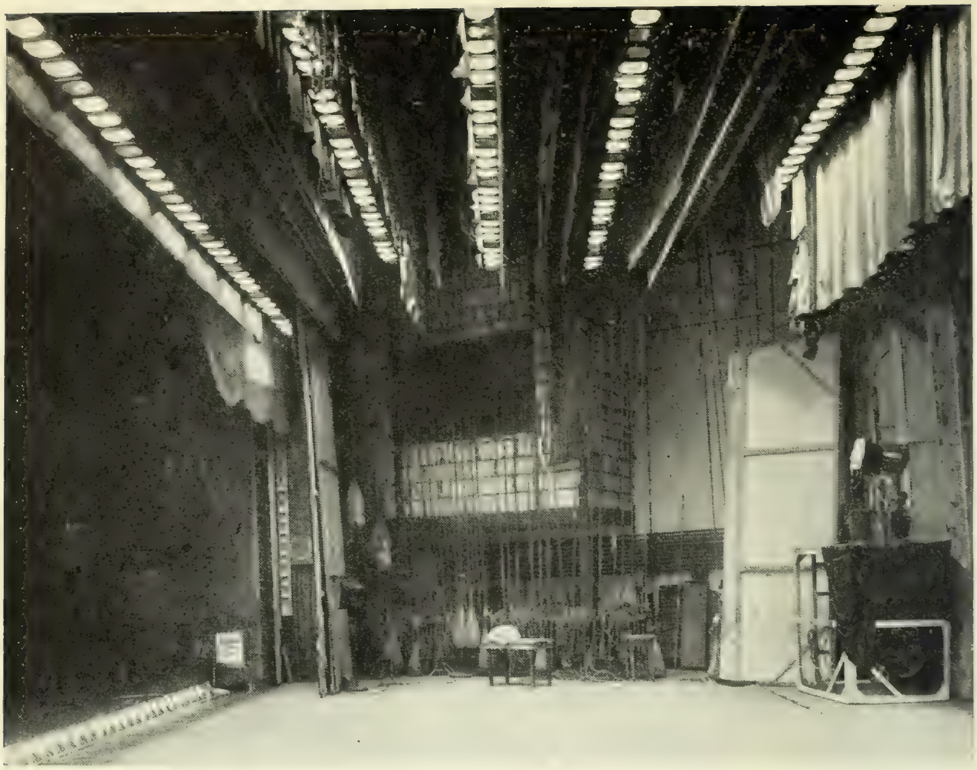

Fig. 9.—View of theater stage lighted by borders, footlamps, and strips of a new type.

Fig. 10.—View from auditorium of stage shown in Fig. 9.

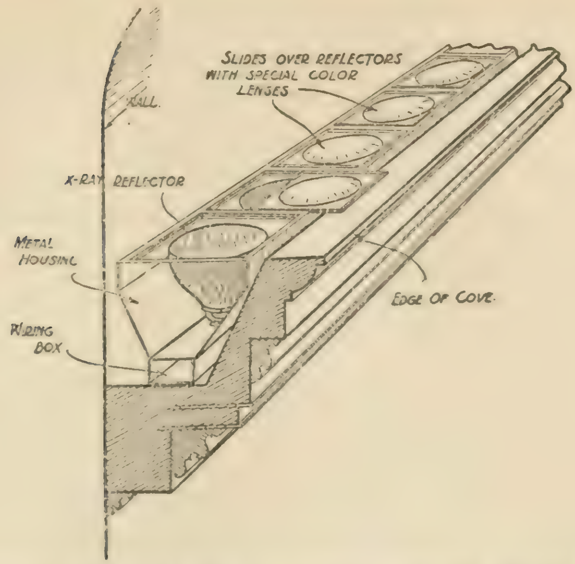

Fig. 11.—Perspective sketch of cove for theatre showing placing of special color lighting equipment.

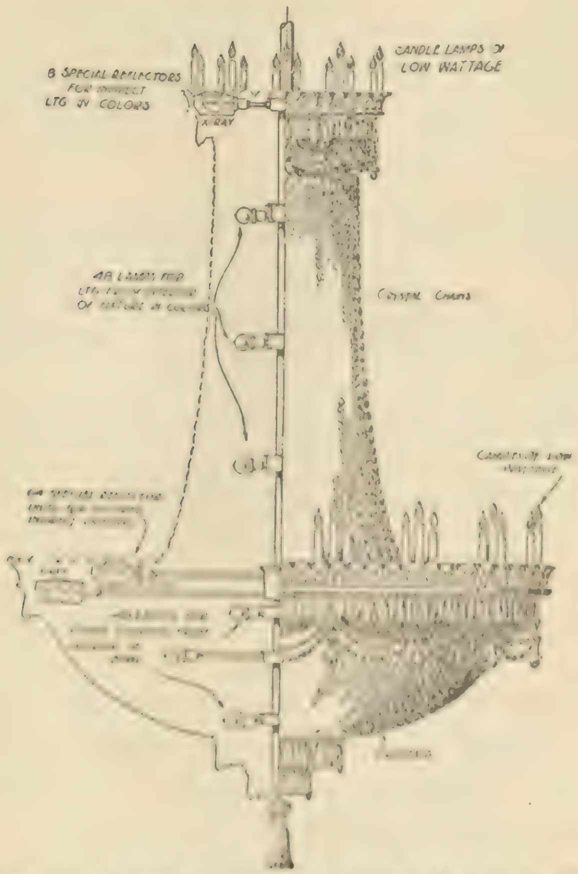

Fig. 12.—A modernized crystal fixture equipped for indirect lighting with color variations.

producers are getting away from the long established styles or conventionalized methods for stage lighting. Opportunity exists here for putting the lighting features of the theatre on a more rational and economical basis. The illumination of the stage by direct reflection, with its reasonably exact control of the light, seems to be a step in the right direction as against the old borders and "foots" whose rays were unconfined.

A view of a typical stage with the new type of equipment is shown in Fig. 9. As will be noted, the borders, footlamps and proscenium strips all contain reflectors for each individual lamp, enabling the producer to direct the light where it will be most effective. In many instances with the old type borders too much light was thrown against the back wall or in other locations of the setting. Control of the light by the proper use of individual concentrating or diffusing reflectors tends to a more natural distribution of the light.

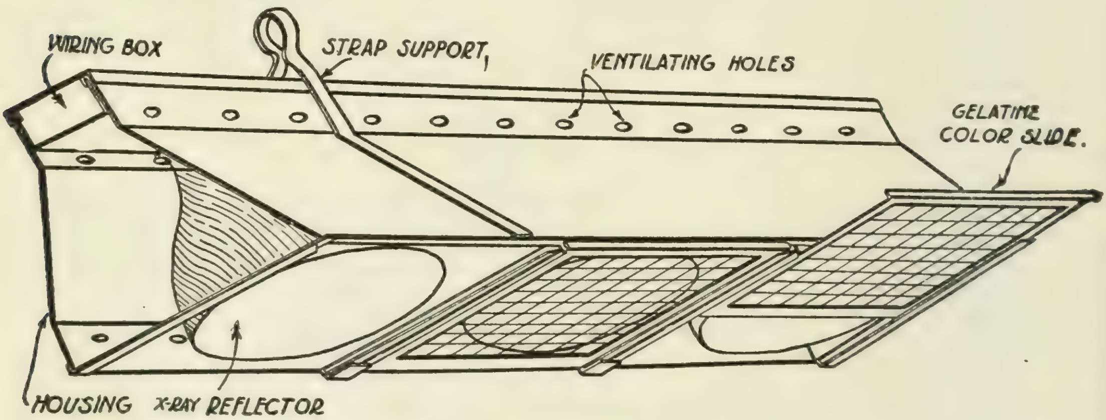

Fig. 13.—Perspective sketch of border light equipment showing reflectors, removable color slides, wiring box and strap support.

The results of the new stage lighting method from the viewpoint of the audience are shown in Fig. 10, while in Figs. 13, 14, 15 and 16 are given diagrams in perspective of the make-up of the borders, footlamps and strips which form a part of this new equipment.

Many theatre men consider that the footlight is wrong in principle, that the light given from this equipment causes shadows on the faces of the actors to be inverted or unnatural, especially when the action is near the front of the stage. A legitimate demand has, therefore, sprung up for equipment that will provide a greater horizontal component in the lighting of the stage. In a

number of instances it has been provided by installing a special outfit in the front of the balcony, as illustrated in Fig. 17. By careful construction the light beams are shielded from the eyes of

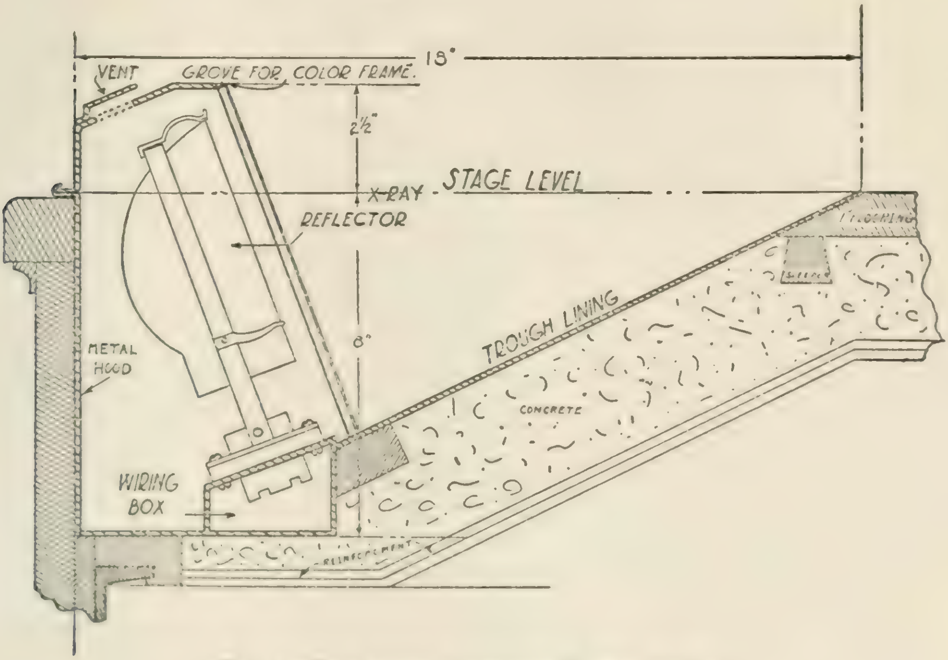

Fig. 14.—Cross section of new type of stage footlight

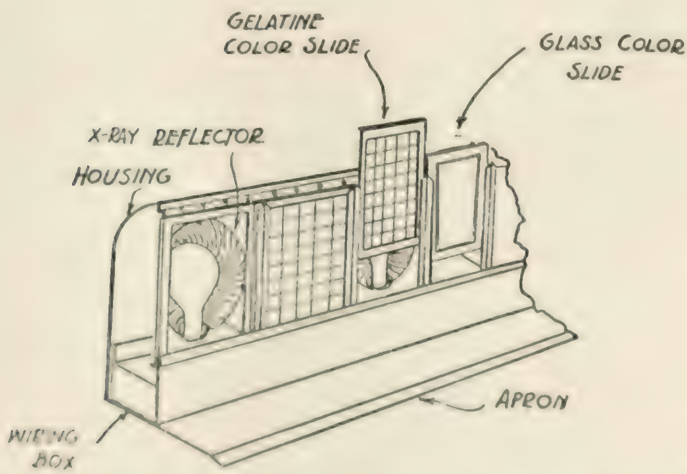

Fig. 15.—Perspective sketch of footlight equipment showing reflectors, wiring box, housing and apron, also method of using glass or gelatine color slides.

persons seated in the boxes and in the front portions of the theatre. Units are in many cases arranged to provide colored beams as well as the usual unfiltered lighting, and have been found to be very effective in wiping out the objectionable upward shadows.

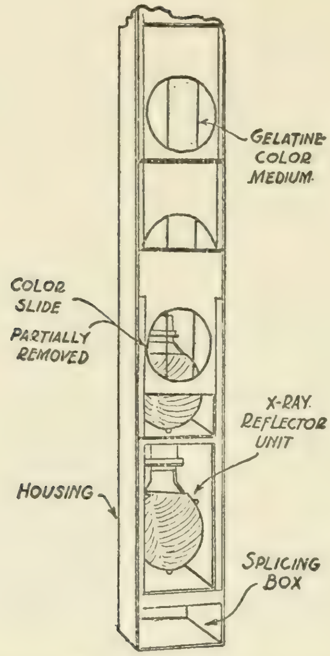

Fig. 16.—Perspective sketch of new type of proscenium strip, with wiring channel, reflectors, and slides for color mediums.

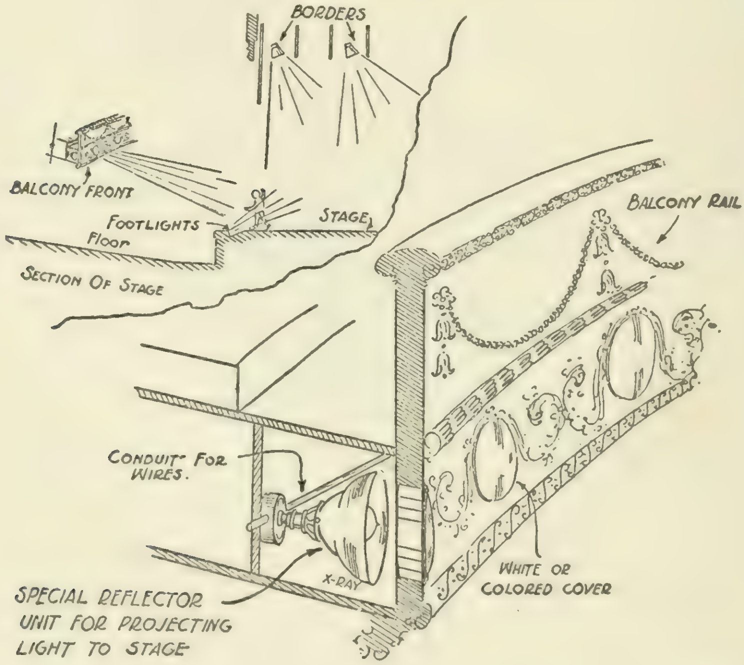

Fig. 17.—Diagram of scheme to provide horizontal lighting component for theatre stages.

COLOR IN SHOW WINDOW LIGHTING.

The art of the display decorator is being enlarged by the use of color in show window lighting. Until recently he has had at his

disposal only one quality of light, white light, but with equipment newly developed, he is given *"color,"* another tool with which to work.

There is a time-worn statement comparing the show window to the stage. This analogy will become more complete as the application of color to show window lighting progresses. There is no doubt that the display decorator has many times looked with longing at the marvelous effects produced upon the stage and realizes what can be done with his own window setting by the general use of colored lights in producing sunlight effects, the atmosphere of moonlight, delicate pinks, greens, etc.

This new application suggests to us its unlimited possibilities, when we remember that every individual show window affords a different setting or picture for which there is a most suitable color tone. As Mr. Powell recently said in talking before a convention of display men, "Men's clothing for instance might logically demand a daylight color to display them to best advantage. For an exhibit of ladies' lingerie, possibly a delicate pink for general illumination might be most suitable. A setting displaying spring wear, where it is desired to create a "Summery" atmosphere of the Florida climate,—here might easily be utilized a yellowish green light produced by careful mixing of the proper colors."

The mechanical means recently produced for securing colored lighting in show windows is shown in Figs. 18, 19, 20 and 21. The outfit consists essentially of a metal frame that fits over the bottom opening of the window reflector and holds a slide containing the color medium.

It has been found for this particular application that a colored gelatin is the most satisfactory medium for producing colored light in show windows. The gelatin in this case is supported in a slide by a screen of fine steel strips, stamped from a single sheet of metal. The color frame is so designed as to provide ample ventilation for the complete unit.

The colors are readily interchangeable. When the ordinary white light is desired, the slide may be left out of the frame. The frame interferes in no way with the light from the open reflector, and, since it is inconspicuous, does not detract from the appearance of the lighting equipment.

The color frame permits of the reflectors being installed on about 12 in. centers. Lamps of the 150-watt size should be used. For color lighting the show window may be wired in the usual manner when only one color arrangement is desired at a time or with the lamps connected by a more elaborate wiring system to a flasher. The latter will no doubt be used for spectacular purposes largely, but not for show windows in which tones or atmospheres of color are used.

The application of this device will enlarge the effectiveness of show window displays and open up a field for research and production of moods and atmospheres most suitable for various types of displays.

A device of this nature will of course at first be used for spectacular purposes to a large extent but will gradually take its legitimate and permanent place in show window lighting. The window decorators that are truly artists, and of whom fortunately there are increasingly great numbers, will use color lighting as a permanent part of their equipment.

THE FUTURE OF THE ART.

It has been said that the lighting of the future, which does not take into account the value of color effects, can be likened to a scheme of decoration in black and white, a scheme that is sufficient and satisfying only to those who are color blind.

The absolute necessities of lighting have now been supplied. The scientific development of lighting units and the control of light has reached a stage which makes the present a most opportune time for the development of a decorative art in lighting. The indications are that this new era is upon us; not only will merchandise be more startingly and effectively displayed, theatres more beautifully illuminated in harmony with the dramatic production, but residential interiors will be more comfortable and restful, with the work of the decorator accentuated by the proper color lighting effects.

Add to all this, possible startling results in the flood-lighting of towers, monuments, buildings, which by combination of projectors, color lenses and flashers may seemingly be consumed in a flare of colored fire or be made to revolve in the sky.

The work that has been done in the application of color in lighting, both for commercial and decorative purposes, has been met

Fig. 18.—Show window having reflector equipped for producing color lighting effects—first color slide removed.

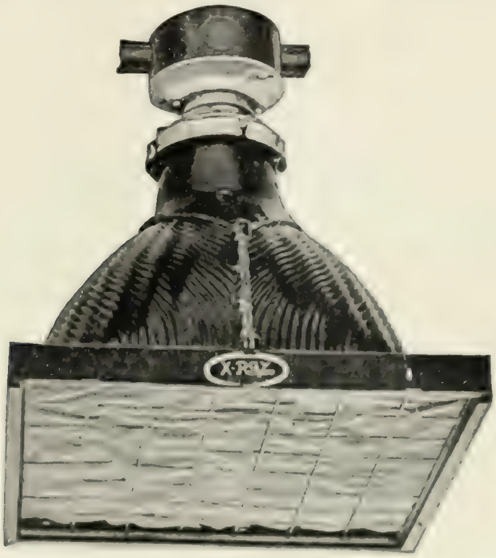

Fig. 19.—A new device for color lighting in show window attached to reflector.

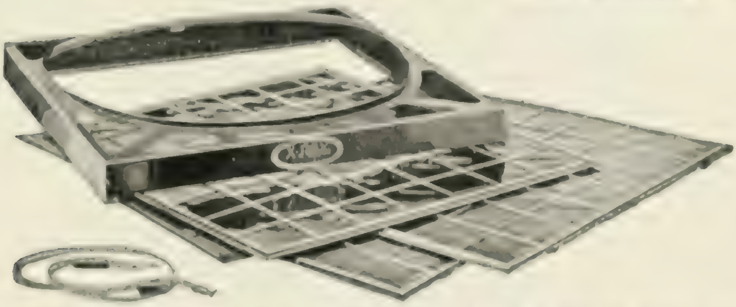

Fig. 20.—Complete "color-ray" outfit for a single window reflector, consisting of one color frame, harness for attaching to reflector, four color screens of red, amber, green and blue.

Fig. 21.—Method of attaching color frame to reflector by means of asbestos cord harness.

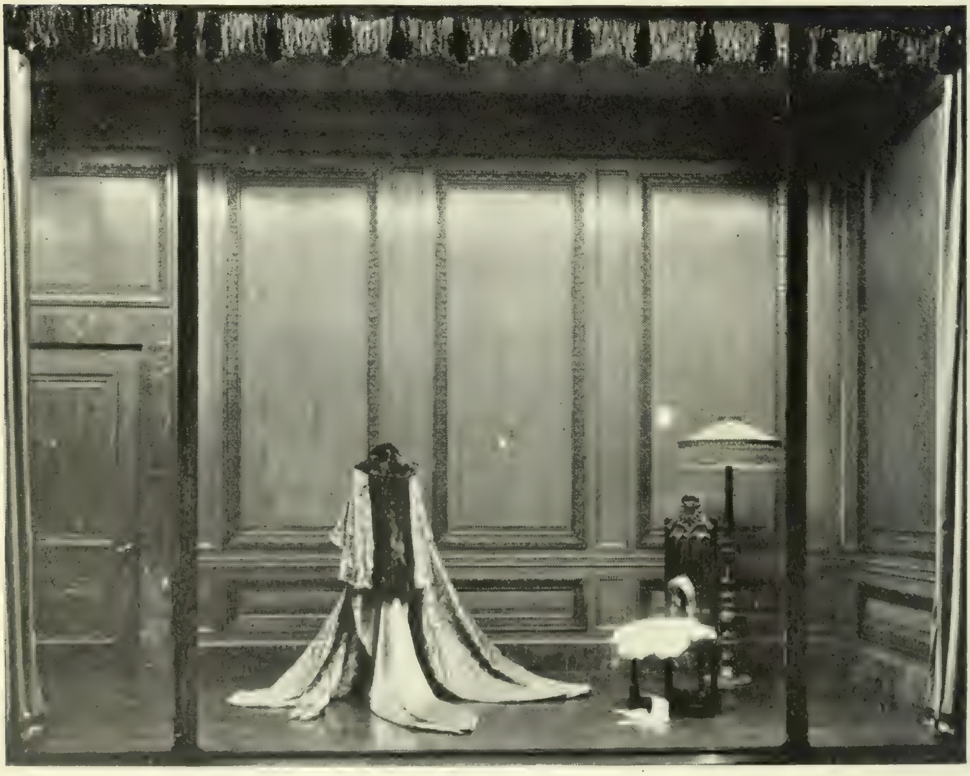

Fig. 22.—Type of display calling for dignified lighting effect; color can be most effectively used to bring out the elegance of this setting.

with such public approval that it has spurred on those interested in this development so that the future evidently holds in store great surprises for all of us.

Much of the artistic value of lighting is still to be evolved. Our present task, therefore, is to help unlock for the future some of the world's color wonders, so that, as far as illumination is concerned, the generations to come may live in an atmosphere of refined color.

DISCUSSION.

S. G. HIBBEN: I believe and hope that we have about reached the time when the illuminating engineer in residence lighting especially, will not mean merely watts or lumens when he speaks of efficiency. The proper title for such an engineer might well be a "lighting artist."

That color in lighting has not received greater attention in the past is no doubt due to the economic necessity for more light at minimum cost. We have had to first make good working illumination universal, and upon that initial basis of education we may now begin to build the artistic and the more comfortable conceptions of home lighting. The increased efficiency of the modern lamps, and I hope the awakening esthetic tastes of the average residence owner, will help popularize color lighting.

In my own home I have a mission table lamp which I equip with four green shades in summertime, and with amber shades in winter. The psychology is obvious.

In some European residences the use of color in illumination has been worked out with beautiful effects. One scheme uses a table center-piece or medallion of heavy lace, studded with colored miniature lamps in pleasing patterns. In the garden of one French villa, marble statues were flood-lighted with a bluish-white light, while under the trees and rose arbors were placed huge vases with rose tinted light streaming from their tops. Such effects are really beautiful and could be readily reproduced in the summer gardens of our own homes.

J. R. CRAVATH: Those who are starting in on color lighting installations should remember that the general lighting of an interior with any one predominating color causes the striking effect of that color to wear out soon as far as our eyes are concerned.

For example, you come into this room, lighted as it is now, with lamps that are slightly colored, you are aware of the color and it is very pleasing. Later on, you are not aware that there is anything unusual.

If color lighting is to be strikingly effective it must either be changed frequently or the color must be localized in some one spot, so that it will be in contrast to the color effect in other places. That general principle has to be observed if color in lighting is to be used effectively. However, for other than striking effects colored light has also a place. The best example of this is the regular use of yellow, orange and red to make surroundings and countenances appear more pleasant, in which case the effect is not striking but subconscious.

J. L. STAIR: The application of a lamp similar to those used in this room giving a warm or a pinkish light just occurred to me. Recently an experiment was made in a display case where wax figures are shown. The salesman replaced every other lamp with a tinted lamp and the improvement was very marked. The manufacturer of these wax figures seemed to be very well pleased with the effect of the tinted light, and considered it a very valuable help to the display.

CENTRAL STATION METHODS FOR SECURING HIGH LIGHTING STANDARDS IN OLD HOMES.*

BY O. R. HOGUE, J. J. KIRK AND E. D. TILLSON.

PREFACE.

A survey of 1500 residences in Chicago shows that lighting for the great bulk of homes is a travesty. What shall be done to better their standard of lighting? We cannot sell fixtures or wiring due to the fact that eighty per cent. of the homes are *rented flats* and for others present prices are too high. Portable lamps offer only a limited solution since an equal percentage of the total residences have only one baseboard outlet per seventeen rooms, and that one outlet is often not usable for either portable lamp or appliance.

The remedy offered in this paper is the rehabilitation of the fixtures as found, using fabric shields, converters, inverters, adapters and other accessories that can be removed at the expiration of a lease, leaving the fixtures intact. Accessories and portable devices to be such as to reduce glare, introduce color, enlarge the light source areas, effect concealment, and finally produce more beautiful lighting effects.

It is urged that a "Lighting Art Service" be inaugurated either by the Central Station (if it conducts a merchandising business) or some aggressive electrical dealer in each city, and that this service be sold to the renting public in a large way. It is thought that the merchandising sales would be very heavy; lighting revenue would be increased, the load factor improved, and finally the cause of good lighting would be advanced in fields that have not heretofore been exploited.

A remarkable paper was presented before the Chicago Section of this Society last December by Mr. W. A. Durgin. The subject was, "Our Perennial Travesty, Home Lighting." It appears that this paper has not been given the publicity that it deserves. The talk was based on the results of a survey of 750 Chicago homes. We would like here to repeat some of the facts disclosed by Mr. Durgin, but taking into consideration the now completed

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

survey embracing 1500 customers of the Commonwealth Edison Company.

This Central Station carries upward of 320,000 residence customers on its lines; of these it has been computed that

5,000 are what we will term Class A customers.
15,000 are Class B customers.
133,000 are Class C customers.
123,000 are Class D customers.
44,000 are Class E customers.

In rough explanation of these divisions: Class A is what we might call the wealthy; Class B, the well-to-do; Class C, the average citizen; Class D, clerks, poor tradesmen and unskilled laborers; Class E, the very poor, those who use electricity in a very meager way—not surveyed.

Eighty per cent. of the homes in the four classes surveyed, taken as a whole, were apartments. That statement is extremely important and bears repeating. Eighty per cent. of all the homes were "flats."

What does the surveyor find on entering these homes? First of all, in the two main rooms of the house, the living and dining rooms, 78 per cent. of all ceiling fixtures are of the old fashioned direct shower type, or shower and dome with two or more sockets, generally, a combination gas and electric fixture. The predominating equipment elsewhere, is the single-socket direct pendant.

Lighting from concealed sources, with its almost infinite possibilities is represented in the proportion of 16 to 6937 fixtures, or in other words, is simply *not there.*

Taking the four classes as a whole, we have the following:

Per cent. total fixtures of direct type....................	97.0
Per cent. total fixtures of semi-indirect type...........	2.8
Per cent. total fixtures of totally indirect type.........	0.2

A number of other facts are apparent from an examination of Table I.

In round figures the typical Class A home contains the following lighting equipment:

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Fig. 1.—Living Room "before"—Note fixture glare and harsh deep shadows. No. 3067 x 10 glassware. A 150-watt clear amber dipped lamp is used. The silk shade is home made, of amber silk with voile over-skirt. A blue silk shaded table lamp was made up from a jardiniere offered by the mistress of the house, using an inexpensive metal cover and socket such as is sold by almost every electric shop.

Fig. 2.—Living Room "after"—all lights on.
Here is the living room again. You will note that we have considerably moderated the ceiling fixture by the substitution of opal-amber dipped lamps for clear bulbs; also by discarding of glassware in favor of small silk candle shades of golden tone. So revamped, the fixture is intended to serve merely as a colored transparency, and in fact becomes quite a beautiful one. To furnish adequate light for reading, sewing and piano use, the floor lamp was converted into a semi-indirect standard, using Central Electric socket husk No. [illegible] and Sudan inverted bowl.

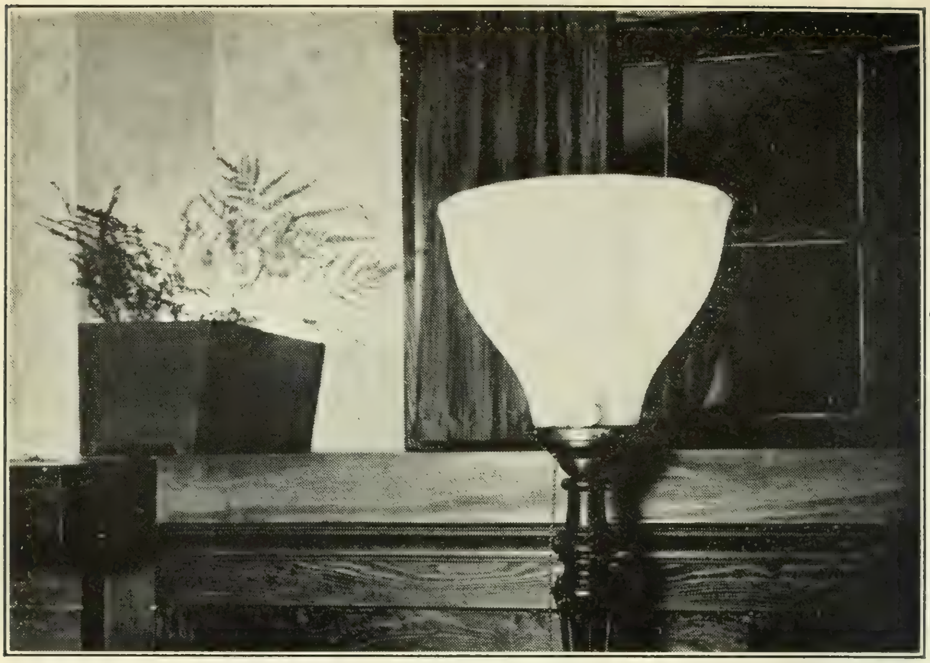

Fig. 3.—Shows details of converted floor lamp and "concealed source" lighting by means of flower boxes.

This living room happened to be built with two fairly deep recesses, one over each bookcase. These were utilized as shown. Four home-made flower boxes were installed, one per corner. Each is provided with 4 10-watt lamps; two amber dipped and two a fairly deep green. These are on a 3-wire circuit with "one-two-off" switch and are plugged into the same baseboard outlet that provides for floor lamp. Preserved ferns and flowers are placed in each. Thus there is a choice of a number of different light sources—each attractive, each of low brightness and with a distinctive color tone. A wide choice of intensities is also obtainable.

Fig. 4.—Bedroom "Conveno-Lite" of the Schweitzer & Herz Co., Chicago, used in combination with opal glassware and small silk shades, thus converting it into a semi-indirect fixture. The brightness in this case has been reduced from 9,000 to 75 millilamberts with a much greater uniformity of apparent brightness across the luminous surface; also, we can have a range of intensities without discomfort or conflicting unsightly shadows.

10 ceiling fixtures (including drop cords and single pendants)
12 wall brackets
1 floor lamp
3 table lamps
and only one out of every two homes, a furniture lamp, such as dresser candles, table candles, bed lamp, etc.

Class B homes as follows:

11 ceiling fixtures (including drop cords and single pendants)
5 wall brackets
1 floor lamp
2 table lamps
with only one furniture lamp for every three residences.

Class C and D homes are similar, averaging as follows:

9 ceiling fixtures (including drop cords)
1 wall bracket
2 floor lamps for every three homes
1 table lamp for every three homes
1 furniture lamp for about every ten homes.

Fifty-six per cent. of all glassware found was that relic of barbarism, the clear glass shade, either roughed inside, roughed outside, or with a molded pattern. This glassware, as we all know, exhibits most harmful and distressing glare. Brightness measurements made on it with common sizes of lamps give values of from 8,000 to 12,000 millilamberts. Twenty-nine per cent. of all fixtures exemplified the more modern practice of using opal glass, although most of the opal encountered was of a cheap character, and very bright. Art glass accounted for 13 per cent. of all glassware (mainly table lamps and dining room domes) while the balance of 2 per cent. comprised Holophane, cut glass and silvered glass.

So much for glassware, whether good, bad or indifferent, with which 56 per cent. of all fixtures were equipped, but unfortunately 31 per cent. of the total number had no shade at all, while 13 per cent., consisting of wall brackets and portables, were equipped with silk or parchment material.

TABLE I.—TYPES OF FIXTURES FOUND IN THE VARIOUS ROOMS FOR FOUR CLASSES OF RESIDENCES VISITED.

CHICAGO RESIDENCE SURVEY.

Class A.

	Direct	Semi-ind.	Indirect	Ceiling	Wall	Floor	Table	Furniture	Dome with pendants
Living rooms	624	16	1	72	339	68	148	20	5
Dining rooms	398	9	0	111	290	1	11	3	12
Bed rooms	270	4	0	86	128	10	32	15	0
Kitchens	175	1	0	114	61	0	0	0	0
Baths	147	1	0	50	98	0	0	0	0
Halls	137	6	0	83	50	3	6	1	0
Sun parlors	178	17	3	96	22	25	52	0	0
Porches	141	5	0	119	27	0	0	0	0
Closets, pantry, etc.	133	0	0	105	26	0	0	0	0
Miscellaneous	290	9	0	144	129	0	19	7	0
	2493	68	4	980	1170	107	268	46	17

Class B.

	Direct	Semi-ind.	Indirect	Ceiling	Wall	Floor	Table	Furniture	Dome with pendants
Living rooms	367	15	6	109	132	56	78	11	7
Dining rooms	325	7	6	237	86	0	6	7	19
Bed rooms	167	1	0	109	33	3	11	11	0
Kitchens	128	0	0	101	27	0	0	0	0
Baths	123	1	0	61	62	0	0	0	0
Halls	126	3	0	92	30	0	7	0	0
Sun parlors	138	21	0	87	8	23	40	2	0
Porches	107	2	0	92	17	0	0	0	0
Closets, pantry, etc.	119	0	0	109	10	0	0	0	0
Miscellaneous	215	6	0	93	54	15	51	6	0
	1815	56	12	1090	459	97	193	37	26

TABLE I.—(*Continued*)

Class C.

	Direct	Semi-ind.	Indirect	Ceiling	Wall	Floor	Table	Furniture	Dome with pendants
Living rooms	212	23	0	104	33	36	54	7	7
Dining rooms	125	4	0	106	14	1	7	1	40
Bed rooms	123	0	0	101	11	1	4	7	0
Kitchens	107	0	0	100	7	0	0	0	0
Baths	107	0	0	81	26	0	0	0	0
Halls	83	1	0	70	12	0	2	1	0
Sun parlors	143	12	0	100	2	21	30	5	0
Porches	102	0	0	89	12	0	0	0	0
Closets, pantry, etc.	138	0	0	131	7	0	0	0	0
Miscellaneous	157	11	0	103	10	7	47	2	0
	1297	51	0	985	134	66	144	23	47

Class D.

	Direct	Semi-ind.	Indirect	Ceiling	Wall	Floor	Table	Furniture	Dome with pendants
Living rooms	132	24	0	102	5	18	27	3	4
Dining rooms	79	4	0	73	2	0	7	0	36
Bed rooms	110	0	0	96	8	0	2	4	0
Kitchens	102	0	0	101	1	0	0	0	0
Baths	100	0	0	87	13	0	0	0	0
Halls	105	0	0	73	31	0	1	0	0
Sun parlors	169	4	0	100	17	26	30	0	0
Porches	100	0	0	95	5	0	0	0	0
Closets, pantry, etc.	112	0	0	108	4	0	0	0	0
Miscellaneous	87	13	0	74	13	13	0	0	0
	1096	45	0	909	99	57	67	7	40

For the two important classes, namely, C and D, representing 80 per cent. of the central station's customers, there was only one baseboard outlet for every seventeen rooms. One result is the wholesale habit of plugging portables and appliances into ceiling fixture, removing lamp, and frequently the glassware as well. The cord is usually draped gracefully like a clothes-line about the room in this home-like endeavor.

Superficially, the connected load appears quite gratifying, but lamp abuse, misuse and chronic unuse causes a very considerable shrinkage. Most important in the series of causes is the prevailing type now obsolete shower fixture. For example, you have already found, if there is a shower fixture in your apartment living room, fitted with high power lamps and c. r. o. glassware, that one of the lamps lighted, and hanging low in front of one's face usually is quite enough for one evening. He will probably decide that the other three lamps can stay unlighted, or be removed, or be thrown away. The blinding glare (of several thousand millilamberts), the ghastly white color and the harsh, sharp shadows from one lamp is enough, without adding to the punishment. And yet the room is under-lighted.

You will note that one of the greatest assets of electric lighting, namely, control and utilization of color, and beautiful color effects, is in this survey conspicuous by its absence. Likewise the supplementary use of pleasing transparencies, such as electric candles, night lamps, bed lamps, etc., etc.

There is nothing attractive, helpful or comfortable about the lighting as found, and no reason why the customer would desire to use it except when compelled to do so, namely, during peak hours. The result is, a very peaked load curve, which the central station has through the habit of years resigned itself and has come to look upon as inevitable.

We believe this survey is fair to Chicago, and further, that it is representative of every large city in the country. If so, what are we going to do about it? You may say that fixtures and wiring sold now for new homes is of a better order than that just described; this may be so, but it is doubtful. Look over the stock of the average fixture dealer, you will find about the same line of fixtures, dressed up with new names and, oh, yes—of "period" design, of course, but they give the same lighting effects, prac-

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Fig. 5. Bedroom "before." Showing "light barrage" and generally irritating effect—60-watt B with c. i. o. glassware.

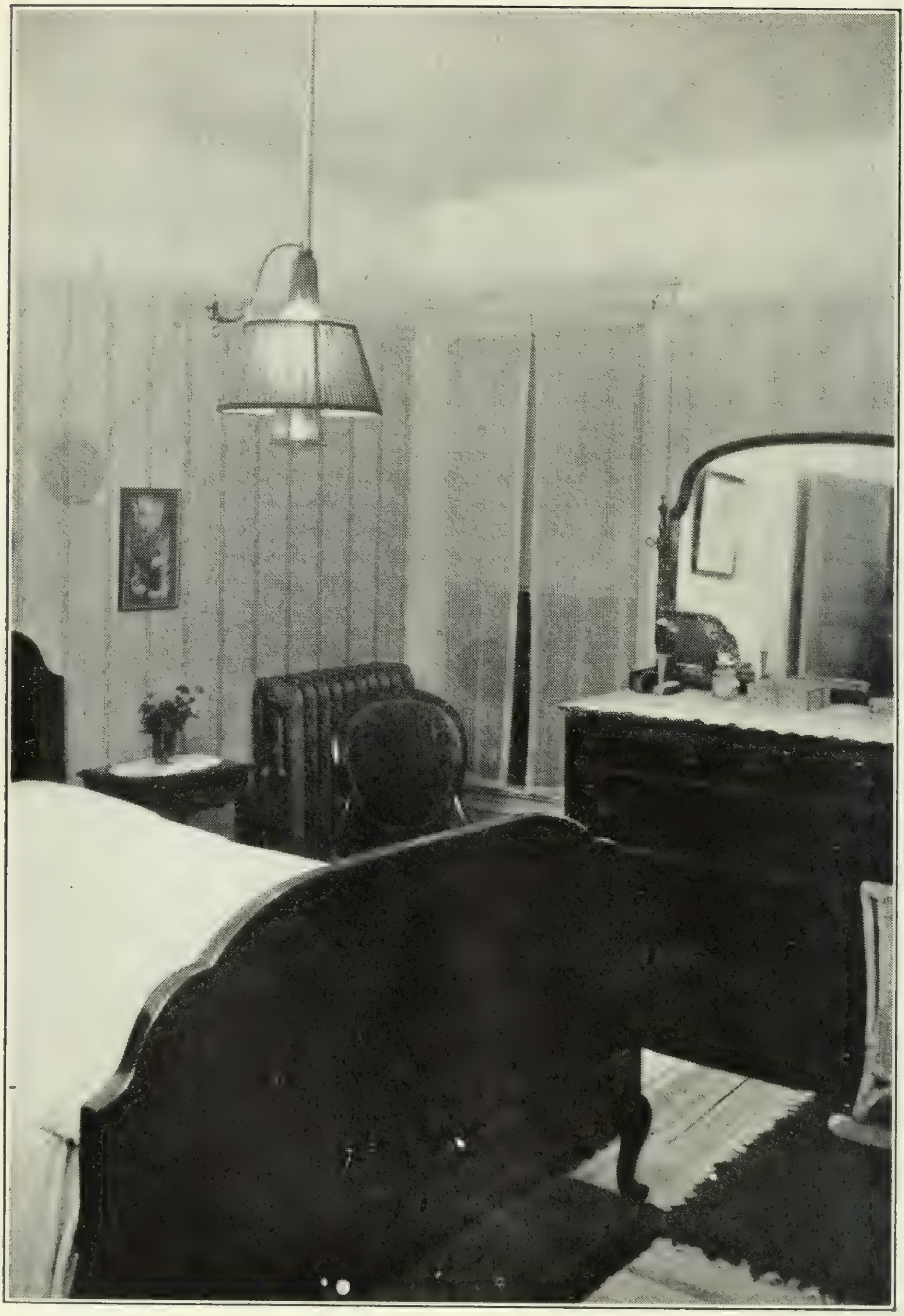

Fig. 6.—Bedroom "after"—Type C lighting mulberry transparencies.
Soft, warm and attractive.

This shows adapter as employed with two concentric shades, one concealing inverted glashware and a 75-watt C lamp, the smaller covering a 10-watt night lamp. A slight twist of lower lamp or plug cuts upper lamp in or out of circuit.

tically—for example our old style shower fixture is now largely replaced by the ultra modern multiple candle fixture, "Queen Mary Anne," we will say, in place of c. r. o. glassware we have bare frosted spherical bulb lamps; of the two one would probably be harmed least by the glassware.

But even if the fixture people were suddenly to fall into the open arms of the illuminating profession—how about the hundreds of thousands of rented apartments that are already built, in which the bulk of our city population lives, and will live for many years to come—250,000 of such "flats" in Chicago alone—80 per cent. of the central station's residence customers. If we are to make any material gain in lighting conditions and lighting load throughout the country, as Mr. Durgin has already suggested, is not this the place to start?

New building is practically stopped in many of our cities due to high prices and scarcity of material and labor. Even if we made each new home a model lighting installation, the nation-wide effect would be small compared with the effect of bringing existing buildings into line with the merest fundamentals of good practice.

Can we sell these customers new fixtures and wiring ? Most assuredly not ! even if we gave fixtures free and merely charged for the erection, there would be no sales. Why ? Because 80 per cent. of the total possibilities are in rented apartments. The existing fixtures belong to the building owner and must be turned over to him intact and in place at expiration of the lease.

But, to illustrate how far we are from giving anything away, just consider a few fixture and wiring prices that prevailed in Chicago during August of this year. For example, a certain representative fixture house priced fixtures as follows:

Average price of multi-socket ceiling fixtures suitable for living room use:

Class A homes....................	$105.00 for single fixture
Class B homes....................	71.00 per fixture
Class C homes....................	50.00 per fixture
Class D homes....................	25.00 per fixture

Lowest priced fixture on display $17.00.

Prices on two-socket wall brackets suitable for—

Class A homes....................	$61.00 per single bracket
Class B homes....................	52.00 per single bracket
Class C homes....................	35.00 per single bracket
Class D homes....................	17.00 per single bracket

and these prices do not include installation.

But some will say, why purchase fixtures at all? Let the customers buy portables! That is a good suggestion. The lighting engineer of one large operating company even goes so far as to recommend to the company's customers that they buy no fixtures of any kind, where portables can possibly be used instead—portables may be easily carted around when the customer moves from place to place and so on—but just here let me remind you of a figure already quoted, that for the classes representing the bulk of our home-lighting business, there is only one baseboard outlet for every seventeen rooms, and further, that the price for installing such an outlet is not less than $25.00 in Chicago to-day.

Furthermore, baseboard outlets are frequently not usable. In dining rooms, kitchens, laundries, pantries and sewing rooms for example, either a floor or baseboard outlet is apt to be awkward indeed and it was found on the survey referred to that where provided by the builder, it was frequently abandoned in favor of some contraption attached to wall bracket or ceiling fixture. Baseboard outlets require stooping. Cords run from them are liable to be tripped over. Then again, floor outlets in a dining room, for example, mean mutilation of rug, table and table cloth if they are to be used in a concealed way. If the portable or appliance can be left plugged in indefinitely, as in a floor, table or furniture lamp, and particularly if these are used near the wall on which outlet is located, then a baseboard outlet is certainly most desirable, but otherwise no.

This is not with the intention of discouraging baseboard outlets. We all regret their scarcity. But it should be pointed out that the baseboard outlet is not a universal panacea; it has its limitations.

Summing up, therefore, we face the following situation, namely, home lighting as found is very seriously lacking. We all desire to see it improved—not merely talked about. We cannot sell the sufferers new fixtures and wiring. Eighty per cent. of them are

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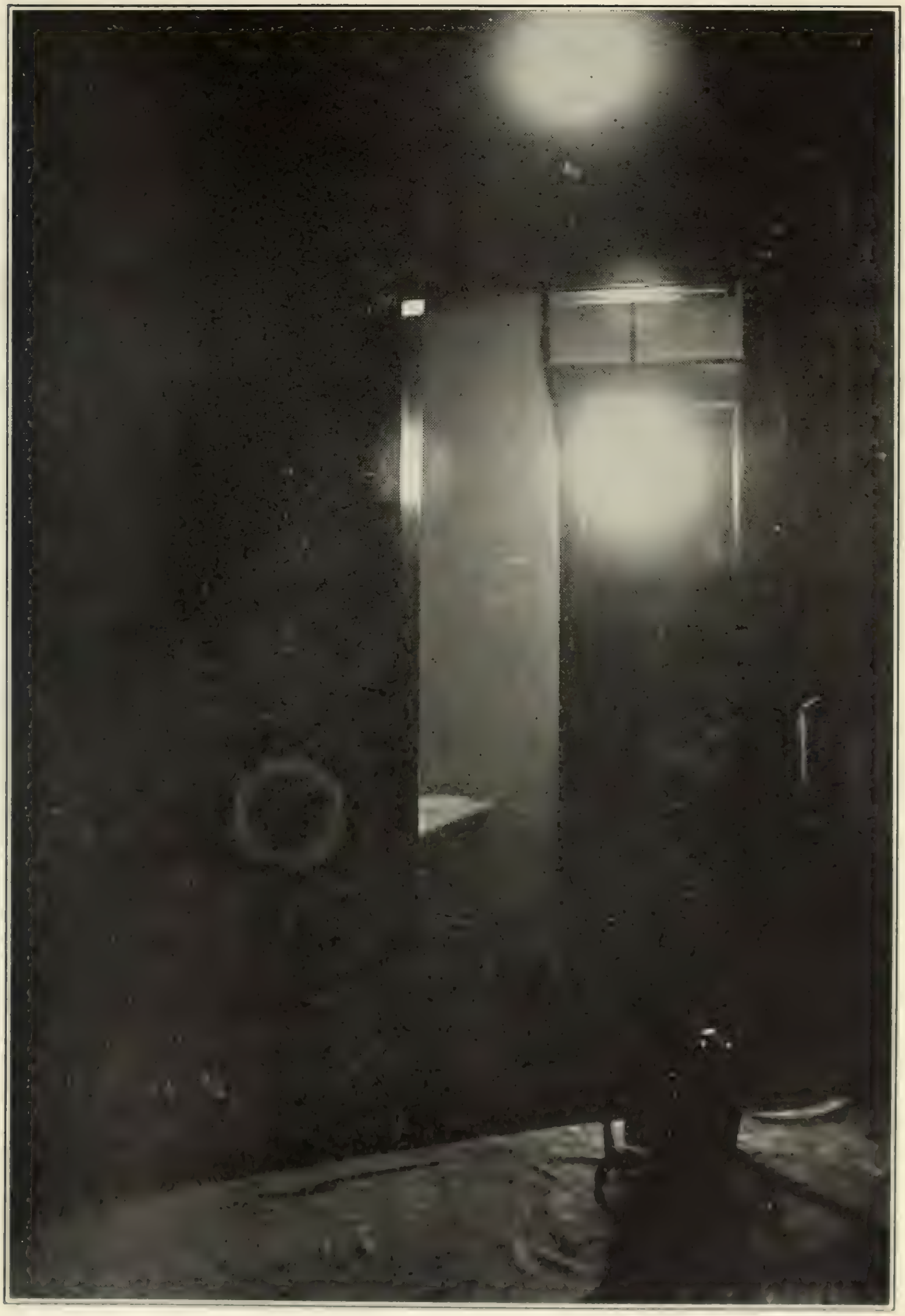

Fig. 7.—Kitchen "before"—Tenant compelled to use gas light for ironing.

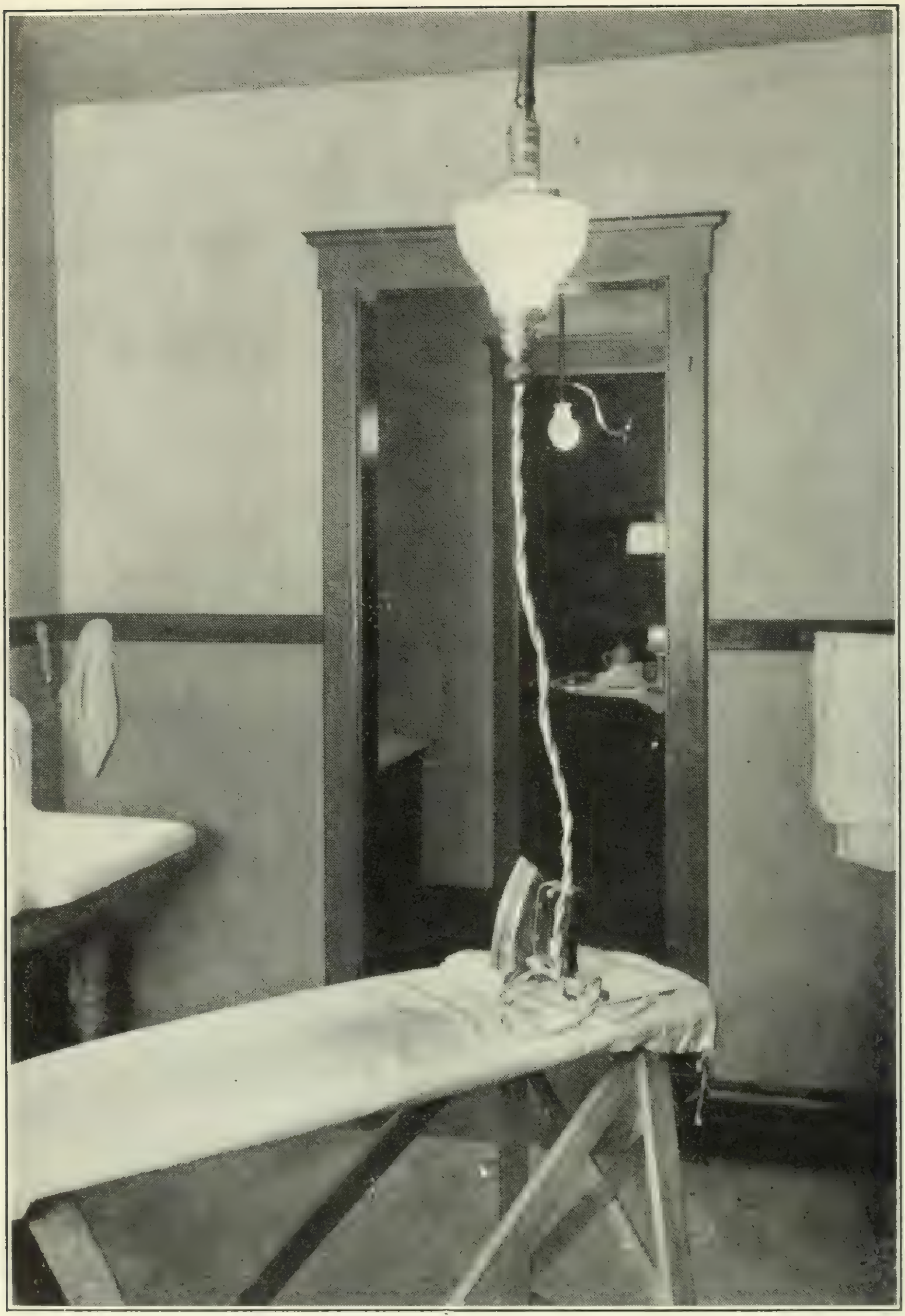

Fig. 8.—Kitchen "after"—Allows working at sink, table, stove or corners of room while facing the wall.

The kitchen is here shown fitted with the same adapter, a 75-watt C lamp and Sudan No. 3067 x 6 in. glassware. Work can be done comfortably in any part of the room, either facing towards or away from the lamps—a condition that certainly did not obtain with the original direct lighting equipment.

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Fig. 9.—Dining Room "before."

The fixture is equipped with "drinking" glasses as you see, roughed outside. The brightness of this glassware with lamps as found was 12,500 millilamberts, whereas the profession has proven a number of times, we believe, that brightness values in the home exceeding 200 millilamberts are disagreeable and even harmful. Note the portable cord to the toaster—this glassware was so deep and narrow that it was necessary to remove it each time the cord was connected, a practice that usually results in a missing shade.

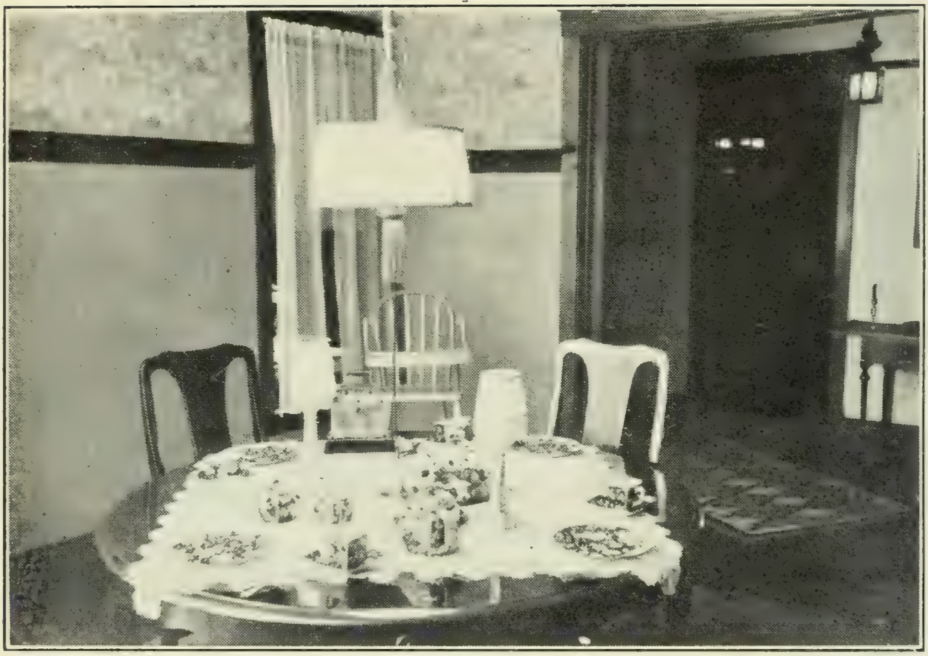

Fig. 10.—Dining Room "after"—Shower feature removed from fixture. Note symmetrical and convenient method for connecting candles and toaster.

In the dining room the former lighting was so unsatisfactory that the erstwhile tenant had taken it into his own hands to remove the fixture bodily. This was resurrected, the charming shower feature removed, and the whole converted into the semi-indirect-direct fixture shown using "Conveno-Lite," Superba No. 551 glassware, a 14 in. silk shade, a 75-watt C lamp, and tassels made from fringe remnants. These tassels conceal the fixture socket and lower receptacle of the adapter.

This view shows the adapter switch turned so as to light the table candles—these use dipped lamps. The table candles were made up from candlesticks already in the house, fitted with candlestick adapters. They plug into the small nickeled gang-plate shown in this slide, which also provides for any table appliance. The whole is symmetrical, neat and quite attractive.

"renters," and prices are too high. We cannot substitute portables except in a limited way, because baseboard outlets are extremely scarce, and even if present, are not always usable.

After all that has been said, what is the solution ? Let us consider the following, and that is, the reconstruction of old style fixtures wherever possible by means of accessories that involve no permanent wiring or fixture hanging devices that can be installed by the renter and removed by him at expiration of lease, leaving the original fixtures intact. Accessories and portable devices that provide superior lighting effects—that give concealment, comfortable fixture brightness, color, warmth, and beauty in the home. Unfortunately these desideratums have not been generally associated with fixture accessories in the past.

Very excellent results can be obtained by the use of ingenuity and simple types of wiring devices, or fittings for converting old fixtures into something artistic and useful. The accompanying illustrations which are used to illustrate the various points in mind will serve to indicate the possibilities.

The old lighting installations are typical of conditions encountered in the average small home, glare, harsh deep shadows and general unattractiveness are characteristic features. The condition might be termed a "light barrage." A fictitious dinginess pervades the room and naturally any refinement or softness in the furnishings is quite thoroughly eclipsed. The rooms have been re-lighted according to good illuminating principles without the purchase of a single new fixture or foot of permanent wiring.

The illustrations represent only a few of the many transformations and we could go on and on to show semi-indirect, stalactite and various types of dome glassware similarly treated —lanterns, colored spot lights, shadow demonstrations, hanging flower baskets, etc., etc. These are all thoroughly practical ideas and nice to talk about—but do we intend merely to talk about them ? How much better to actually carry them into practice on a large scale !

Any aggressive electrical dealer, or central station doing a merchandising business, could furnish a "lighting art service" to great advantage. We have shown that the great bulk of the buying public has its back turned to us at present so far as light-

ing merchandise is concerned, but by advertising, store demonstrations, soliciting, and circularizing, we can gain entrance to many old houses and apartments. Forceful advertising, etc., would carry the idea we have already dwelt upon, and would state that in response to inquiry, a representative would call. This representative could enlarge on the benefits of redecorating with light while emphasizing the fact that present fixtures and wiring would be left intact, the representative to state definitely what he could do for $25, $50, $150, or whatever sum the householder might be induced to spend.

Any orders for material so secured would be filled from a special stock set aside for this purpose in the "electric shop." Such a stock would naturally include standard receptacles, shade holders, adapters, and wiring devices, but in addition, such items as the following:

Full line of silk and parchment shades, shields and transparencies.
Full line of harps, converters, holders and adapters for inverting glassware on ceiling fixtures, wall brackets and portables.
Full line of glassware suitable for true semi-indirect lighting—to be used on inverted fixtures—to be of low brightness and attractive color tone.
Candle-stick adapters.
Table lamp adapters.
Full line of wire shade frames for use where householder desires to make up own shades.
Line of silvered glass and porcelain enameled metal reflectors suitable for totally indirect lighting effects in a home.
Line of urns, flower boxes and basket work.
Full line of portable lamps.

One dealer in Chicago who carries practically the above list in his regular stock, figures that a $600 advertising campaign would lead to merchandise sales of roughly $40,000, and is at present working up such a campaign. At any rate, we thoroughly believe if the idea were sold to a hundred or so homes in any given city, that these would become the most compelling object lessons to the neighborhood and not only to the neighborhood, but to the profession; to central station officials, architects, contractors and others who might be called in to view them; and it is possible that superior home illumination for a reasonable percentage of our total population might date from this occasion. It seems unfor-

tunately true, after fifteen years or so of propaganda by this Society and others, that no widespread results along this line have been accomplished. We are still "agitating" and that is about all.

TABLE II.—Connected Load and Outlets Before and After Lighting Changes. Typical Home (Detached Dwelling).

Room	Connected load in watts			Outlets	
	Before (Gross)	Before Actually in regular use	After Actually in regular use	Before	After
	910	610	1224	19	43

Note.—It should be observed from context that the disparity between gross and "actually used" connected load (columns 2 and 3) was not due to over-lamping, because initially the rooms were badly under-lighted. The trouble was solely due to unsuitable, misused accessories.

CENTRAL STATION METHODS FOR SECURING HIGH LIGHTING STANDARDS IN OLD STORES.*

BY O. R. HOGUE, J. J. KIRK AND E. D. TILLSON.

STORE LIGHTING.

There has been an unusual amount of material written on the subject of industrial lighting during the last few years. Evolved from this mass of discussion are the various State Codes wherein are laid down a set of rules for guidance towards better illumination.

It was not so many years ago that the question was widely asked: Whether reflector manufacturers should or should not produce a standard reflector equipment for industrial lighting. Some lighting men said "No," and again many more said "Yes." To-day there are thousands upon thousands of industrial establishments equipped with r. l. m. reflectors which are in use day after day but no one attempts to say that the r. l. m. is not a success.

Now that the sales of this standard equipment has shown tremendous increases over all other equipment perhaps there is something in this experience which may be applicable to other branches of the lighting field.

As compared with industrial lighting, store or commercial lighting has received but little attention from the Society and may therefore be said to be one of the most backward for that reason.

Leading spirits in the commercial fixture industry frankly recognize and freely admit that they have been very lax in their efforts to standardize their product. This has happened because of the keen competition between rival manufacturers. They individually developed types of fixtures which they believed to be the correct solution of the commercial lighting situation. This has caused them to spend large sums of money in promotional work to convince the buying public that they are right. This intense individual activity has so taken their time and energy that they have overlooked the possibilities and advantages of combining their efforts towards some standard development. As a result

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

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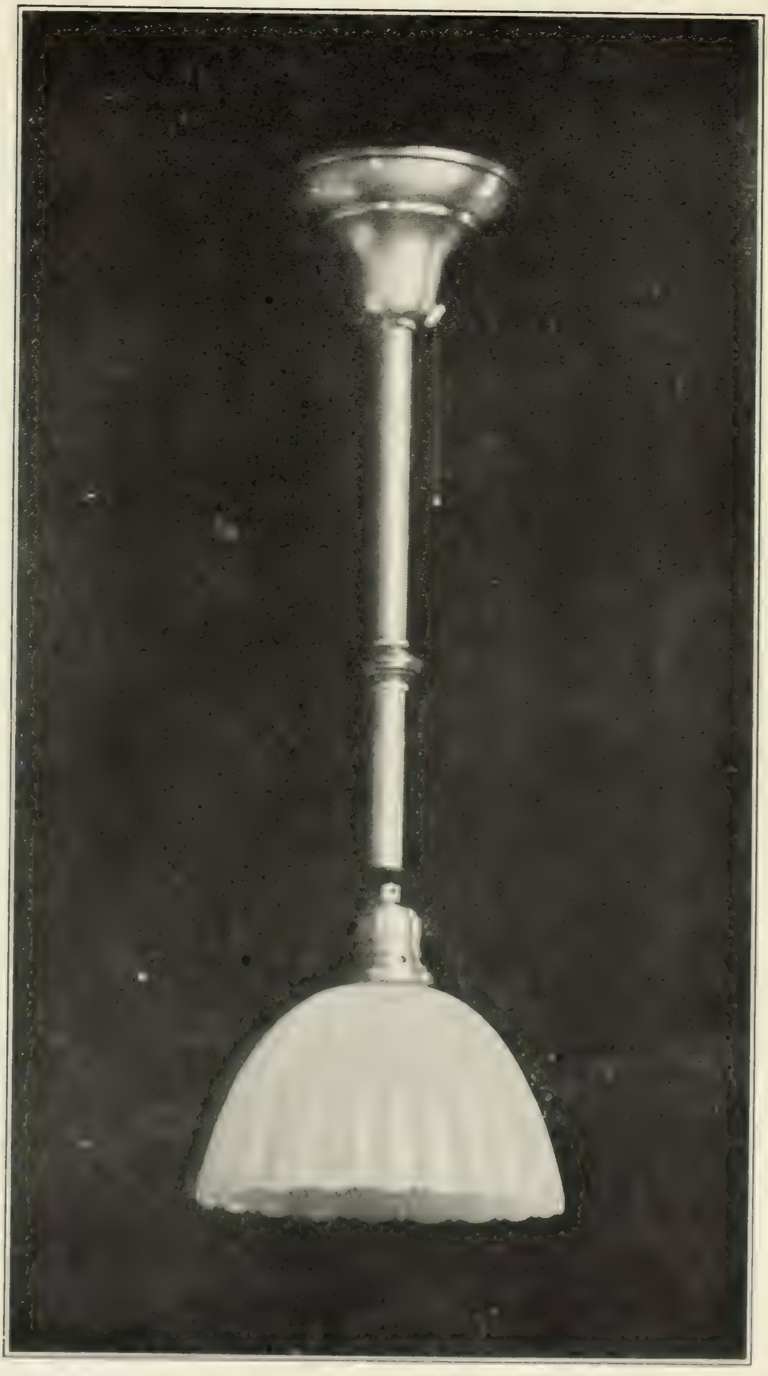

Fig. 1.—Commonwealth Edison Company Standard Store Lighting Fixture No. 632 for "B" lamps.

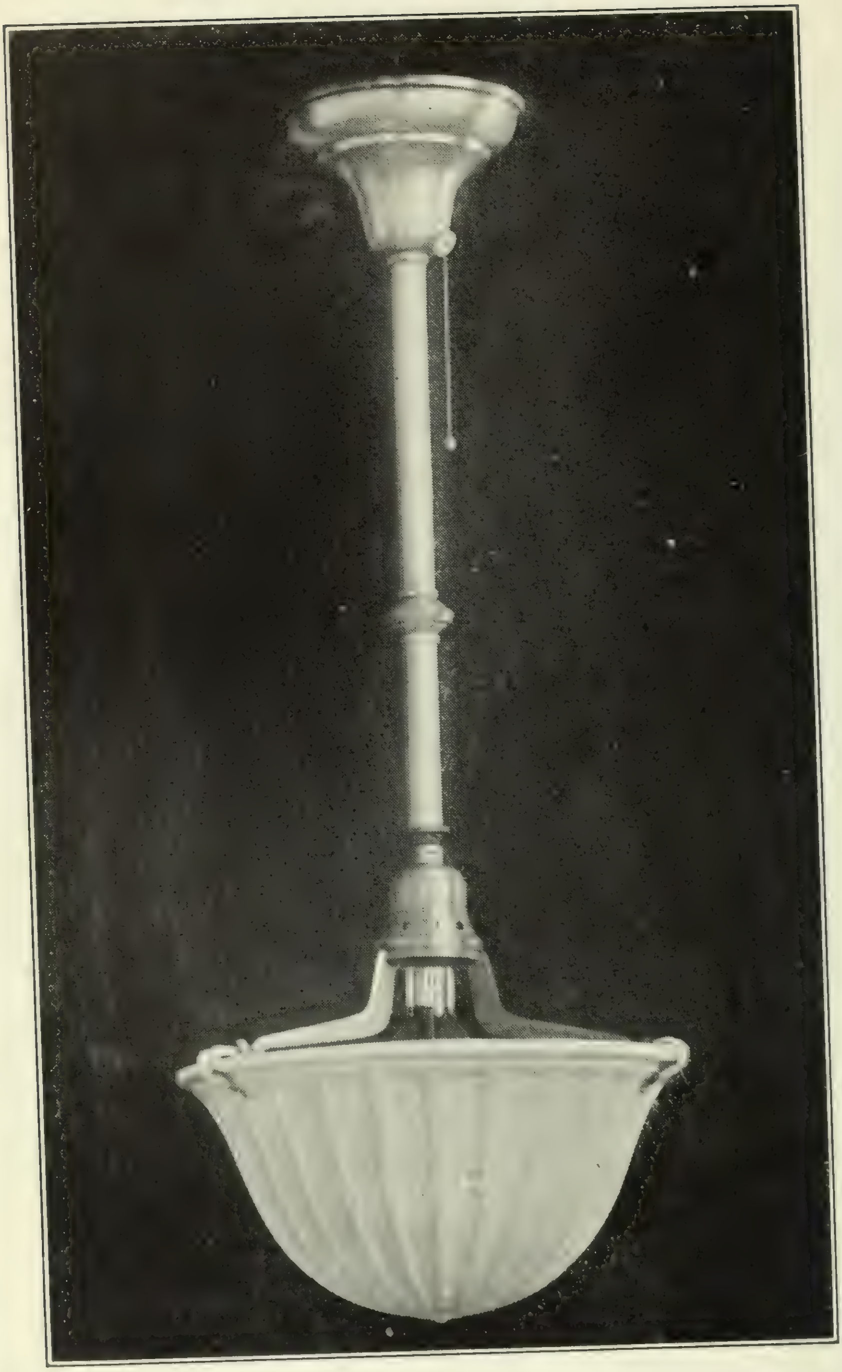

Fig. 2.—Adaptation of Standard Store Lighting Fixture No. 632 for semi indirect lighting.

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Fig. 3.—Assembly of semi indirect store lighting fixture, as shown in Fig. 2.

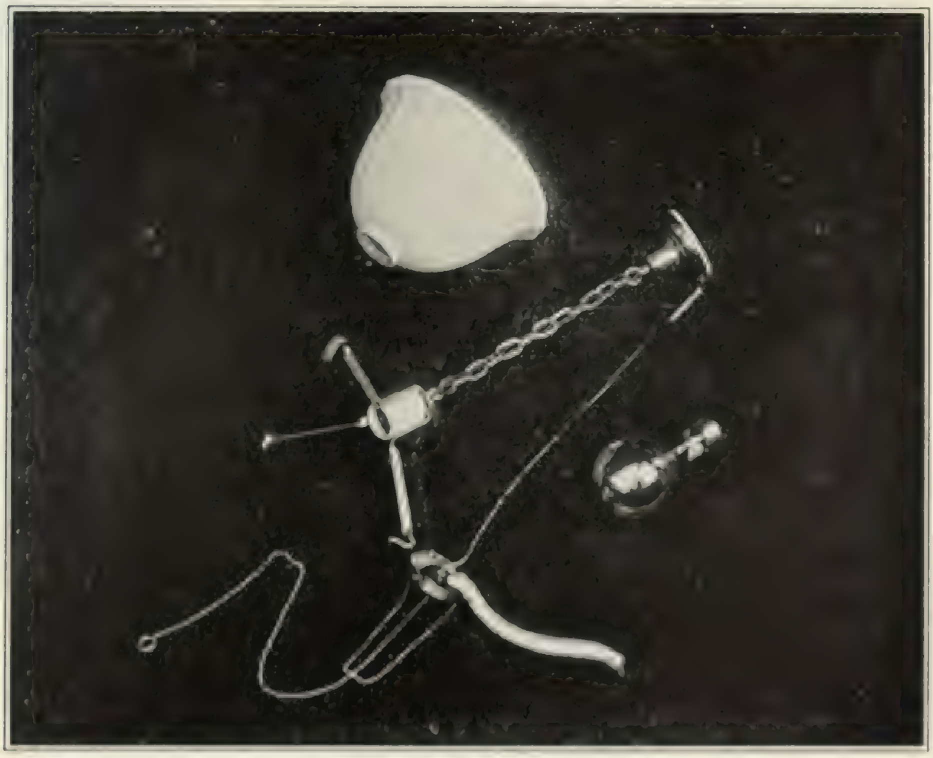

Fig. 4.—"Knock down" "pull clean" unit, as shown in Fig. [illegible]

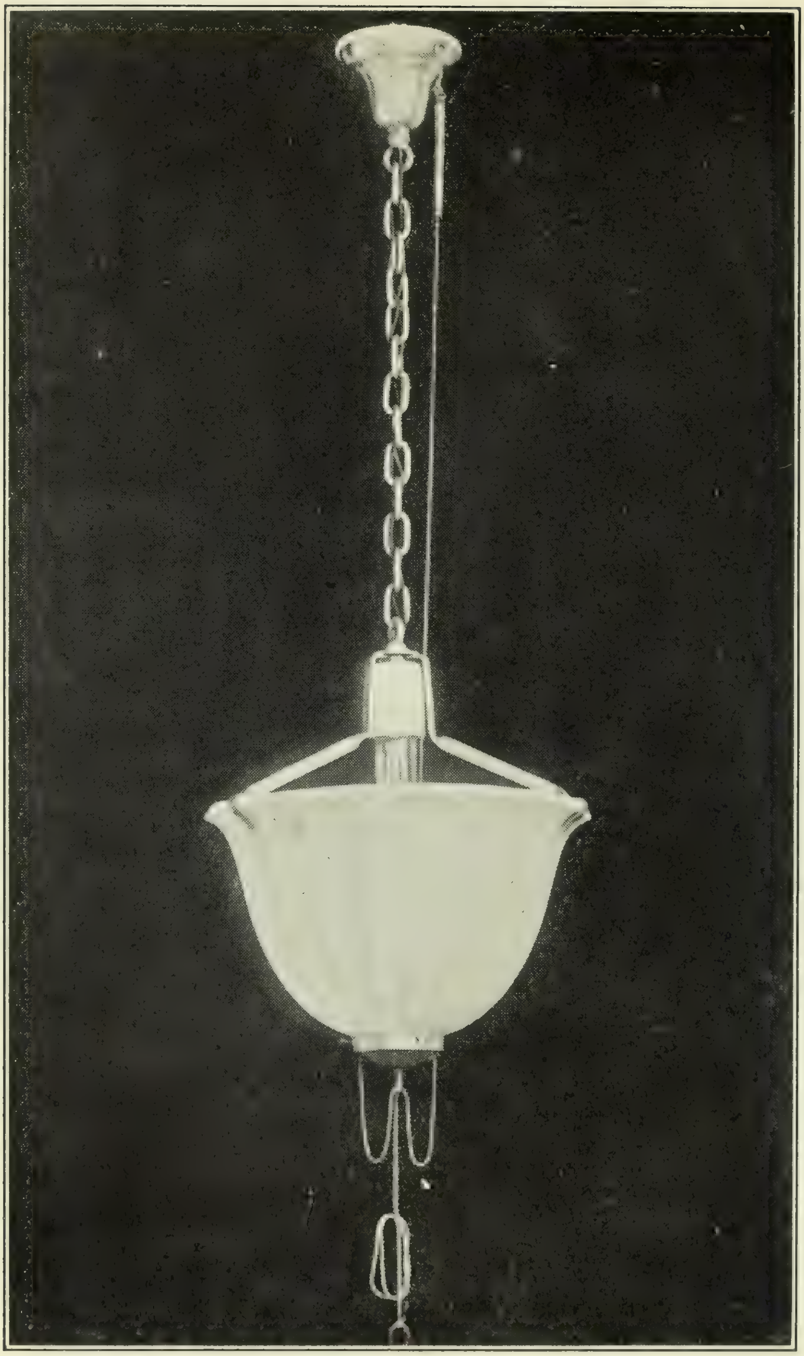

Fig. 5.—Semi-indirect fixture equipped with "pull-clean" attachment.

store lighting equipment to-day is in very much the same position as it was five or ten years ago. Results can be enormously influenced and better relations can perhaps be permanently established if the Society will attempt to find a common ground as they have done in the industrial lighting field.

The advantage of good lighting in industrial establishments is now a commonplace. Every factory owner knows that improved lighting means more and better production and all that goes with it. The advantage of good illumination can be shown to be as beneficial to the store owner as has been demonstrated to the factory owner.

We and others believe that merchandise can be sold more easily and quickly under artificial light in most any store than under natural or daylight. For the benefit of the merchant, the central station and the cause of better illumination, and in order that this may be proven to be a general fact, we suggest that the Society undertake such an investigation. The establishment of such fact by our Society will go far to bring commercial lighting to that more advanced plane held by industrial lighting.

An engineer employed by one of the largest department stores in Chicago in a recent discussion before the Society remarked that when the store wished to dispose of a line of goods, they were moved to a section where lighting intensities were many times higher than prevailed generally throughout the store. Instinctively they must have realized that the psychological effect of the increased intensity would have its result in moving the merchandise.

The progressive merchant knows the value of high intensity lighting in windows as an attracting medium, and hence, its advertising value to his store. Similarly he knows that the proper lighting of his store interior will draw the public inside. We have not yet designed standard equipment with which he can obtain within his store the results which he has a right to expect.

Granted that the longer hours use of higher intensity artificial lighting does increase sales, the Illuminating Engineering Society should place itself in a position to collect data that will establish this fact. Such data could be used by the electrical trade in promoting campaigns for better store lighting.

Having a conviction that store owners would materially benefit by the increased use of artificial lighting, a campaign for better store lighting has been inaugurated by the Commonwealth Edison Company in Chicago. Realizing that the cost of new fixtures is prohibitive to the average store-keeper under present market conditions and knowing that they would not consider new equipment due to its high cost, it was the aim of the company to make this change as easy and as reasonable in cash as possible. Since the company has some twenty thousand fixtures of a standard design installed in customers' premises for use with mazda "B" lamps and not adaptable for use with the "C" lamps (See Fig. 1) it was decided to rehabilitate the present equipment. This rehabilitated fixture was so designed as to conform with present practice in good lighting.

To meet a demand for true semi-indirect lighting our engineers designed a spider adapter with bowl clips to be used in connection with the Sudan bowl No. 6025, as shown in Figs. 2 and 3. This bowl has a pleasing contour and its density is such as to cause a low surface brightness and its color tone tends to improve the general appearance of the store interior. This equipment is applicable to interiors with light colored ceilings or where it is possible to readily resurface the ceiling.

A feature which has been applied to this type of equipment adds to its usefulness and avoids the necessity of frequent cleaning which ordinarily is necessary with this type of fixture. It is known as the "pull clean attachment" illustrated in Figs. 4 and 5. A squegee makes a complete revolution around the interior of the glass bowl operating simultaneously with the pull chain switch. As the fixture is individually controlled, it is impossible to turn the unit on or off without cleaning the bowl. Figs. 8 and 12 show how two styles of semi-indirect lighting units designed for the use of "B" lamps have been reconstructed to use "C" lamps with a resultant higher intensity on the work and an improvement in the appearance of the fixture.

By far the majority of the stores having old style direct lighting units do not readily lend themselves to the use of semi-indirect lighting. To meet this condition the fixture as shown in Figs. 6 and 7 was developed. Here again simplicity of construction and beauty of design mark this change. The glassware was selected

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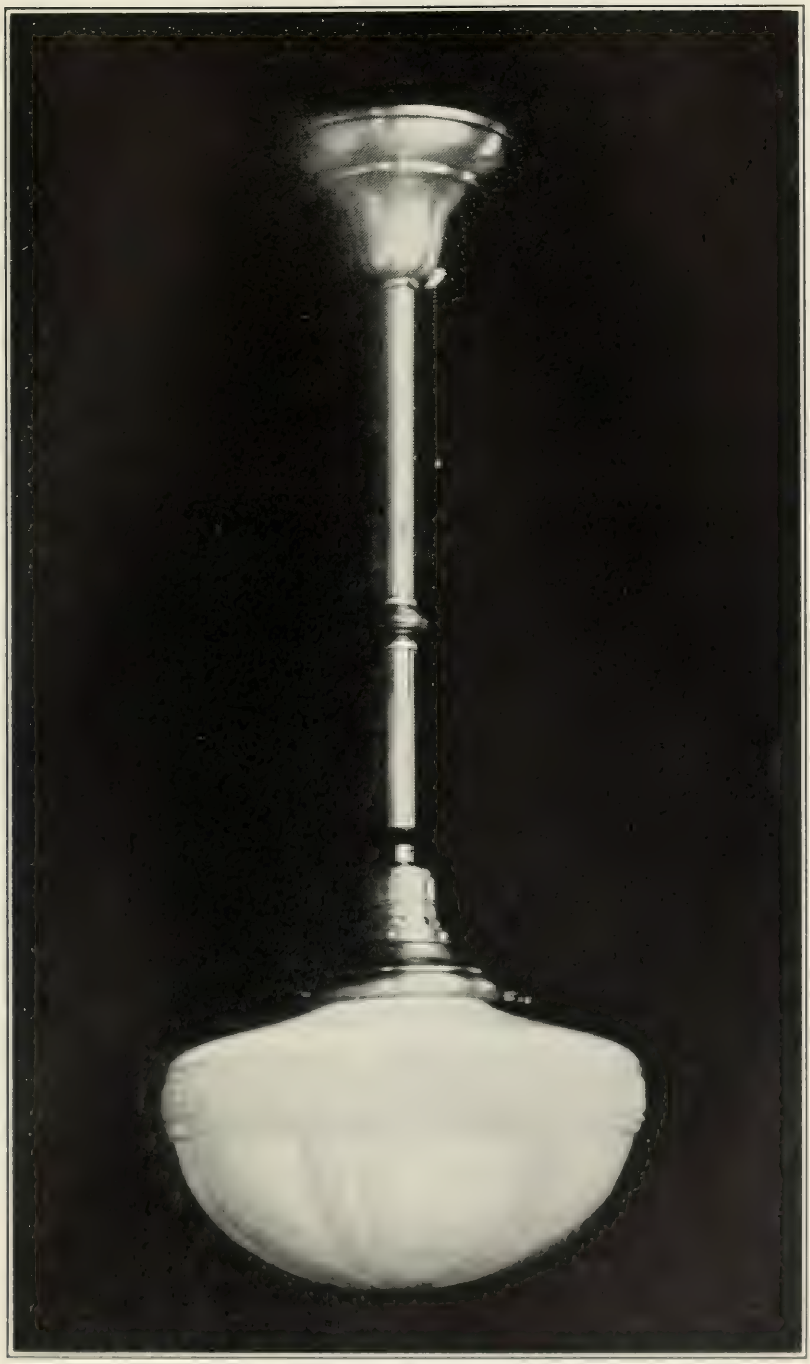

Fig. 6.—An outer adaptation of Standard Store Fixture No. 632 for use with "C" lamps.

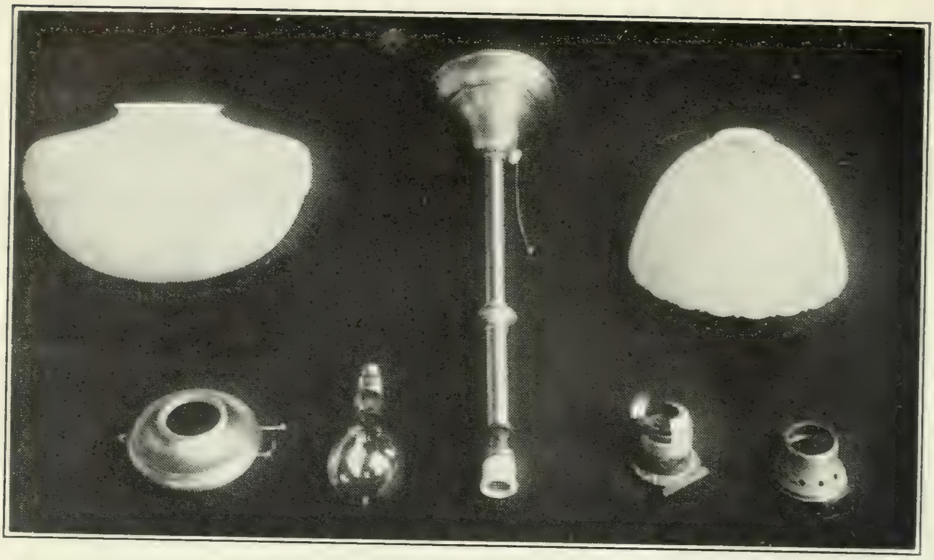

Fig. 7.—Showing parts which go to make up new units. See Fig. 6.

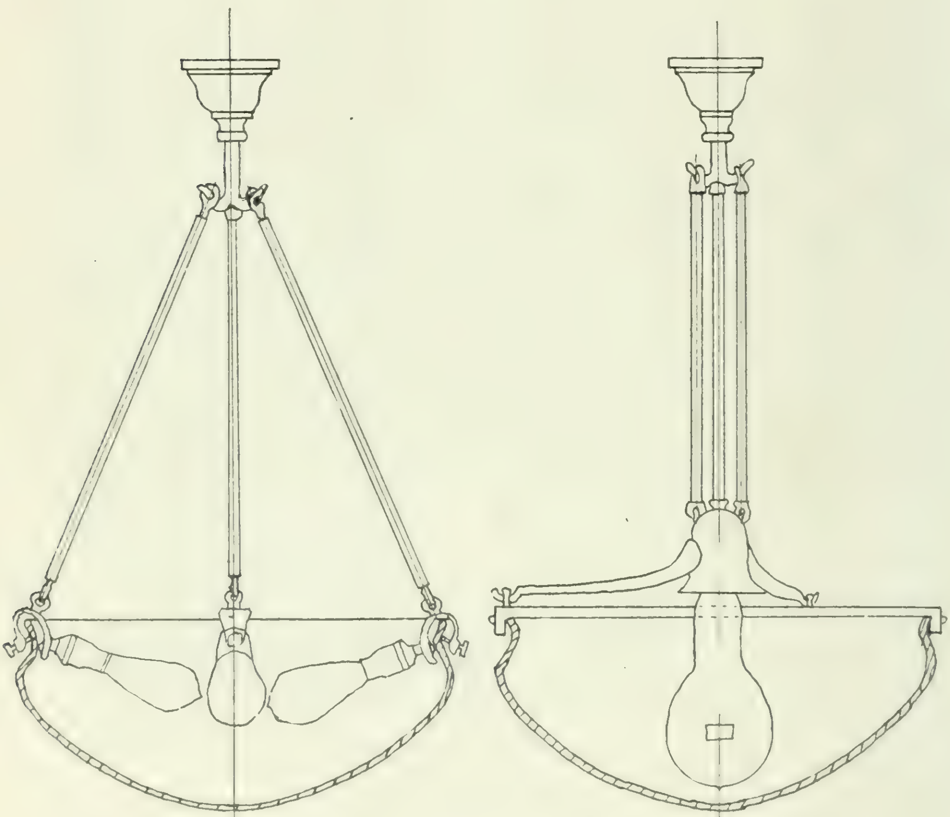

Fig. 8.—Conversion of semi-indirect fixture from "B" to "C" lamps.

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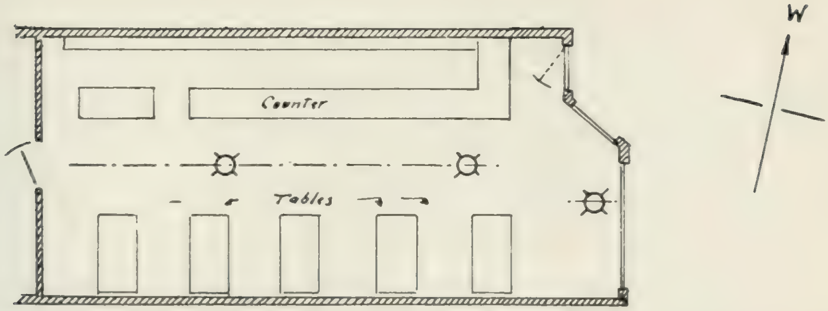
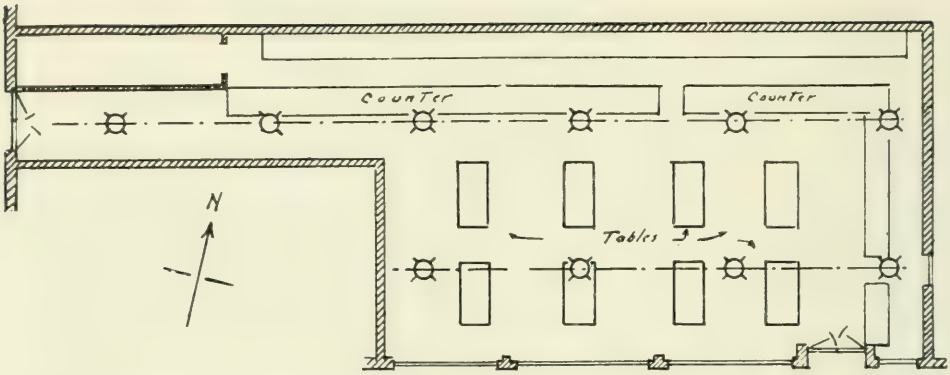


TYPICAL RESTAURANT LIGHTED WITHOUT THE ADVISE OF ILLUMINATING ENGINEER.

GENERAL NOTES

SIZE OF ROOM – 17 x 38	ILLUMINATION IN F.C. – MIN. 1.0 MEAN 2.8 MAX. 4.5
HEIGHT OF CEILING – 12	WALLS & CEILING – PAINTED WHITE
TOTAL WATTAGE – 600 WATTS PER SQ FT – 0.9	FURNISHINGS – WHITE GLAZED COUNTER & TABLES.
EQUIPMENT – 2 – #632 STORE FIXTURES & 1 BARE LAMP.	

Fig. 9.—Plan, view, and details of a typical restaurant.



TYPICAL RESTAURANT LIGHTED BY ADVICE OF ILLUMINATING ENGINEER

GENERAL NOTES.

SIZE OF ROOM – 61FT.-0IN. x 22FT.-0IN.	ILLUMINATION IN F.C. – MIN. 11.0 MEAN 13.0 MAX. 16.0
CEILING HEIGHT – 14FT.-0IN.	WALLS & CEILING - WHITE TILE GLAZED.
TOTAL WATTAGE - 3000. WATTS PER SQ. FT - 3.	FURNISHINGS - WHITE GLAZED TABLES & COUNTER.
EQUIPMENT – 10-300 WATT ENCLOSED UNITS.	

Fig. 10.—Plan, view, and details of a typical restaurant.

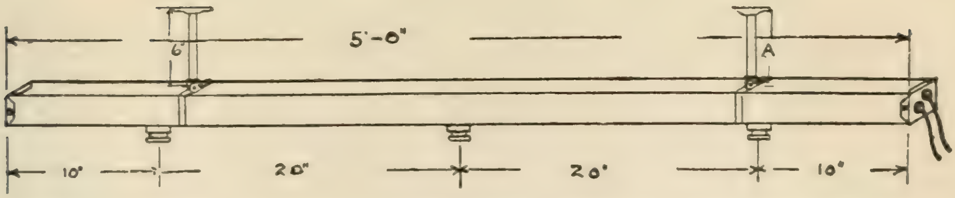


Fig. 11.—Tubing may be had in any length—and outlets on centers desired.

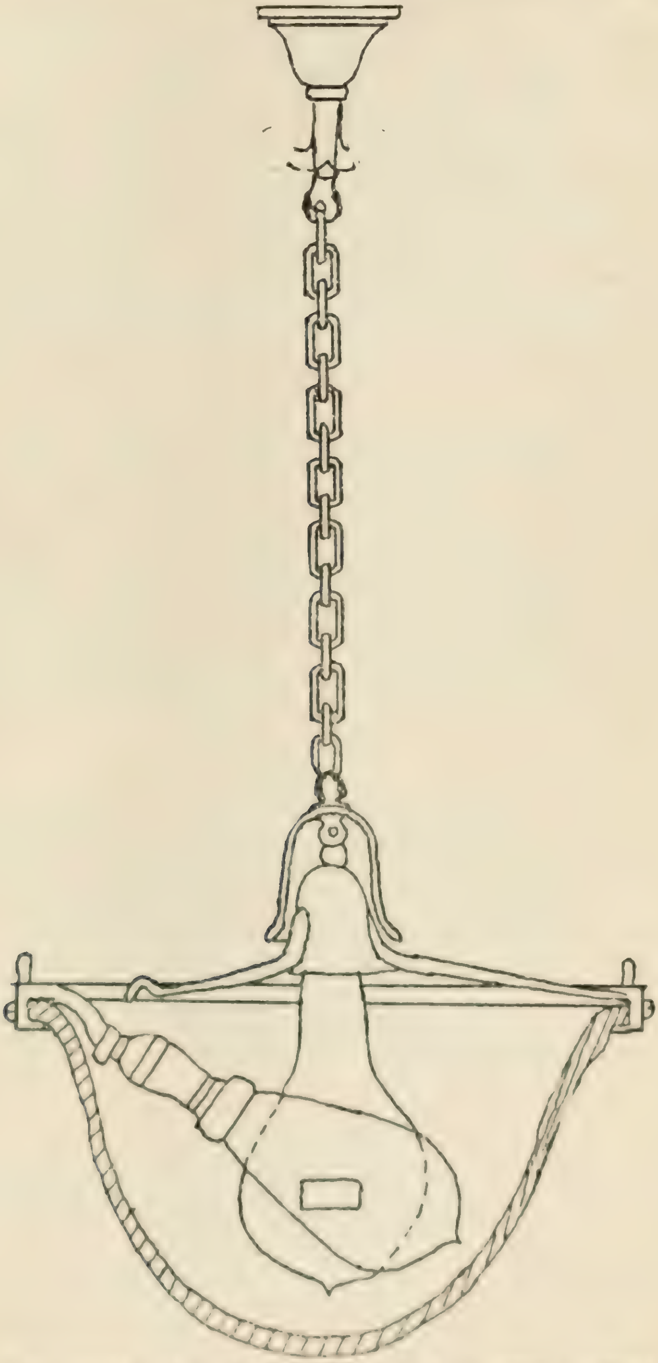


Fig. 12.—Conversion of semi-indirect fixture from "B" to "C" lamps.

for diffusing qualities as well as for general efficiency. Our engineers designed the adapter holder and bowl for use with 300-watt type "C" lamps. Larger size lamps may be used without excessive glare. The fixture is dust and bug proof and will maintain its efficiency over a greater length of time than would be true of some of the other types of fixtures.

It is admitted by all merchants that show windows are necessary to display their wares. However, there is only one kind of a successful window, and that is the kind that sells goods. A show window is a merchant's point of contact with the general public. He cannot hope to attract the attention of the passerby unless his windows are properly lighted. There is an old adage "seeing is believing," and goods well shown are half sold.

It is not the newer stores that need attention, rather it is those stores where only one outlet has been provided for the lighting of the windows.

The cost of wiring outlets for concealed lighting has deterred many a desire on the merchant's part to improve his display. This objection is met by the use of the special tubing illustrated in Fig. 11, which the merchant can obtain, at low cost, including complete equipment with all the necessary fittings. The connection of the wires to the lighting circuits in the building is readily made and entails only a very slight expense as compared with old methods of wiring.

Much credit for exposing the necessity for good lighting belongs to the Society. The public does not demand improvements. In fact, they often resist them. Neither can we say that new things are manufactured to supply a demand. There is no demand. Both the demand and the goods must be created. People have always clung to old fashioned discomforts until some enterprising salesman persuaded them otherwise.

DISCUSSION.

This paper was discussed in connection with the next paper by Mr. Daniels, on "Department Store Illumination."

NOTES ON DEPARTMENT STORE ILLUMINATION.*

BY JULIUS DANIELS.[1]

The fundamental basis on which a large number of business decisions are formed, is a comparison between a merchant's own practice and that of his competitors and others engaged in the same or similar line of business. Lighting engineers have long been aware that this principle is an important factor in securing increased intensities in store lighting. This fact formed the basis for a careful comparison of foot-candle intensities between department stores in the cities of New York, Boston, Philadelphia and Newark.

By means of a foot-candle meter, a series of measurements were taken in each department of the following stores.

NEW YORK.

B. Altman & Co.	Gimbel Bros.
Arnold Constable & Co.	Lord & Taylor
Best & Co.	Jas. McCreery & Co.
Bonwit Teller & Co.	R. H. Macy & Co.
Franklin Simon & Co.	Stern Bros.

BOSTON

Wm. Filene's Sons Co.	Jordan Marsh Co.
Gilchrist Co.	Shepard, Norwell Co.
Houghton & Dutton Co.	R. H. Stearns & Co.
C. F. Hovey Co.	A. Shuman & Co.

R. H. White Co.

PHILADELPHIA

Gimbel Bros.	Strawbridge & Clothiers
Lit Bros.	John Wanamaker

N. Snellenberg & Co.

NEWARK

L. Bamberger & Co.	Hahne & Co.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] The Edison Electric Illuminating Company of Boston.

Readings were taken on either the counter or table level where goods are shown, thus giving the figure with which the user is most concerned. It was found that the majority of stores had similar departments on corresponding floors, *i. e.*, notions, hosiery, stationery, haberdashery, jewelry on the first floor; women's skirts, cloaks, suits and gowns on the third floor, etc., and as the average illumination of the several departments on the same floor did not vary greatly, due to the uniformity of the lighting installation throughout a floor, the comparison is given by floors.

In the following tables the stores are designated by numbers which are not in the same sequence as used where the names are stated. This, for obvious reasons.

The illumination recommended for department stores is six to ten foot-candles for first floors and four to eight foot-candles for others.

NEW YORK DEPARTMENT STORE FOOT-CANDLE INTENSITIES.

	STORE.									
	1	2	3	4	5	6	7	8	9	10
1st Floor	6.0	4.5–6.0	5.5	5.0	4.0	4.0	4.0	3.5	3.0	2.75
2nd "	3.5–5.0	3.5	4.5	2.4	4.0	3.25	2.25	2.5	3.0	2.5
3rd "	4.0	3.5	4.5	2.5	4.0	3.25	3.0	2.75	4.0	3.0
4th "	4.5	4.0–7.0	4.5	3.0	3.5	4.0	2.25–4.0	3.5	2.0	2.5
5th "	5.0	3.5–4.5	—	6.5	4.5	3.0	2.25	4.0	—	2.5
6th "	—	—	—	2.75	3.0–4.5	3.0	2.25	2.75	—	4.0
7th "	—	—	—	—	1.0	—	1.75	3.75	—	—
8th "	—	—	—	—	3.5	—	—	2.5	—	—
Basement	—	—	—	—	—	2.5–7.0	—	4.0	—	—

BOSTON DEPARTMENT STORE FOOT-CANDLE INTENSITIES.

	STORE.									
	1	2	3	4	5	6	7	8	9	10
1st Floor	5.1	4.5	4.2	4.0	3.7	2.9	2.75	2.5	2.5	1.7
2nd "	4.7	4.75	3.7	4.6	3.2	2.7	3.3	2.8	2.1	1.5
3rd "	4.25	2.5	3.0	3.75	2.9	2.5	2.7	2.0	1.6	1.5
4th "	5.5	2.75	2.0	2.6	2.9	3.0	2.6	3.0	2.2	1.5
5th "	4.2	—	1.25	—	2.8	—	1.75	2.4	—	1.5
6th "	3.2	—	—	—	1.0	—	—	—	—	1.6
7th "	3.6	—	—	—	1.5	—	—	—	—	1.75
8th "	2.0	—	—	—	3.0	—	—	—	—	—
Basement	3.2	—	2.75	—	1.7	—	2.0	—	3.5	1.0

PHILADELPHIA DEPARTMENT STORE FOOT-CANDLE INTENSITIES.

	STORE. 1	2	3	4	5
1st Floor	5.0	4.0	3.1	2.1	1.75
2nd "	5.0	5.0	2.0	2.25	1.5
3rd "	2.5	3.5	2.0	2.0	2.25
4th "	1.5	3.0	2.0	1.5	1.75
5th "	4.0	2.0	2.0	1.5	2.0
6th "	—	6.0	—	—	1.75
7th "	—	2.75	—	—	1.5

NEWARK DEPARTMENT STORE FOOT-CANDLE INTENSITIES.

	STORE. 1	2
1st Floor	5.3	2.5
2nd "	3.3	2.5
3rd "	2.0	3.5
4th "	—	2.25
5th "	—	2.6
6th "	—	2.5
Basement	3.75	3.5

This comparison, when presented to the executives of the Boston stores, stimulated an interest in store lighting. It manifested itself immediately by requests from managers for information for bettering conditions. In the case of store 5 in Boston, the superintendent made a personal investigation of store lighting practice in the larger cities as far west as Chicago. Word reached us indirectly of discussions between store men of the lighting in their stores, something they frankly admitted they had never seriously considered before. One store superintendent remarked that on entering the different stores he noted the lighting with as much interest as the merchandise.

The following results can be traced directly to this comparison.

Store No. 1 had under consideration reducing their units from 750 watts per bay to 500 watts. They have now definitely given up this idea.

Store No. 2 has made minor changes on the third floor.

Store No. 3 has increased the sizes of the units on the first and third floors, increasing the consumption 2000 kilowatt hours over a corresponding period last year, or 8.3 per cent.

The entire remodelling of the lighting equipment is also under consideration.

Store No. 4 made changes on the first and third floors, increasing the consumption 4000 kilowatt hours over last year, or 10.5 per cent.

While considering the question of lighting, the management of this store asked for suggestions regarding their display windows, with the result that the old equipment of 100 watt nitrogen lamps on 24 inch centres in trough reflectors used in eighteen show windows, have been replaced by X-Ray reflectors spaced on 15 inch centres equipped with 100 watt C2 (daylight) lamps.

Store No. 5 made changes on the first and third floors, increasing the consumption 4000 kilowatt hours, or 8.3 per cent. over last year.

Store No. 6 changed the lighting installation throughout. On the first floor 27 300-watt units were replaced by 89 300-watt units, the other floors being treated in a like manner. The consumption increased from 14,000 to 38,000 kilowatt hours, or 163 per cent.

Store No. 7 will replace on four floors clusters of 4 100-watt vacuum lamps controlled by electrolier switches, by fixtures designed to hold 500-watt type C lamps.

Store No. 8 increased the size of the units on the second floor from 200 watts to 300 watts, and is contemplating radical changes throughout the remainder of the building.

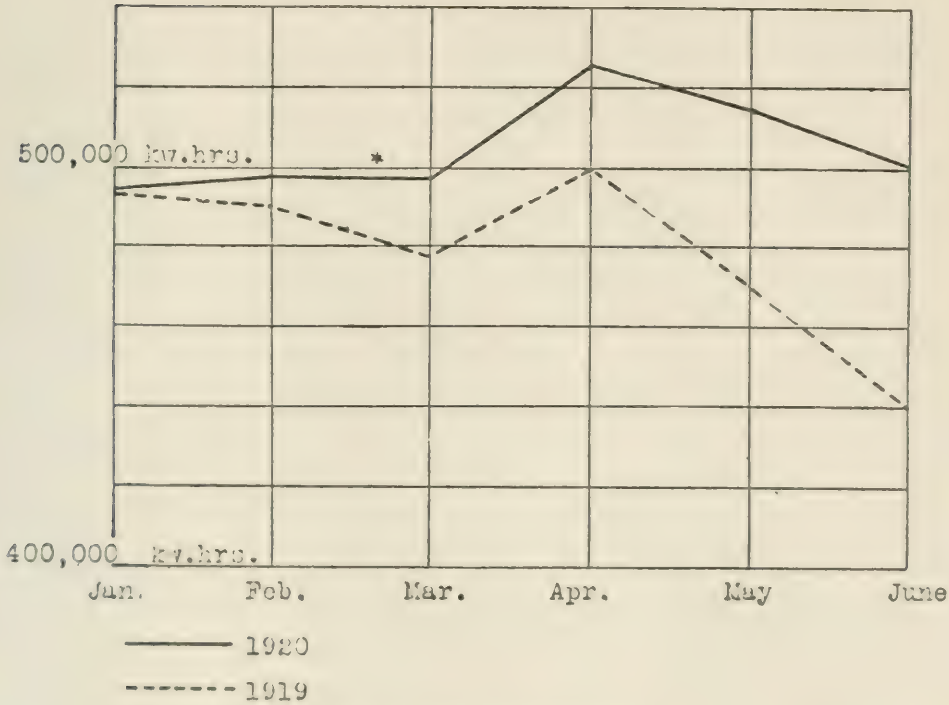
Stores No. 9 and 10 are using 300 watt lamps in over 1200 fixtures, and are contemplating replacing them with 400 watt lamps.

It would not be strictly true to state that the presentation of the comparison was responsible for all the changes made, but there is no doubt but that it was one of the most important factors in securing favorable attention to the subject of illumination.

While obtaining the foot-candle readings for the comparison, observations were made as to the status of store lighting in the management of the store.

The following chart shows the increase in kilowatt hours consumption following the presentation of the comparison.

Consumption of Eight Boston Department Stores.



* Date comparison was presented.

The store managers are receptive in this respect. Unfortunately the source of most of their information on this subject is the fixture salesman. The fixture or specialty salesman constantly drills into his customers' ears the fact that his fixture has a greater efficiency than that of his competitor, with the result that there is a tendency to reduce sizes of units installed rather than to increase them.

The responsibility for the lighting equipment is usually in the hands of the engineer or electrician, whose initiative in advocating changes in lighting is tempered by the constant admonishment by the management to keep down expenses. Final decisions regarding illumination are made by the store principal. Unfortunately most principals believe that lighting is an expense, some going so far as to say that good lighting is a detriment as it allows customers to see the imperfections in goods. This is almost unbelievable in an age when Service First is one of the cardinal principles of a successful business, but it is nevertheless true.

There is no reason for doubting but that stimulative lighting in department stores will increase sales and the efficiency of employees in a similar manner to the increased production brought about by improving industrial lighting. The intensities recommended for department stores are, as stated above, six to ten foot-candles for the first floor, and four to eight foot-candles for other floors. These intensities are by no means excessive, and a trial by any fair-minded executive would soon convince him of the desirability of this intensity of illumination.

A simple method to show what intensities are desirable to examine merchandise, is the following. In a room where the illumination varies greatly, *i. e.*, 0.5 foot-candle to 25 foot-candles, ask a store manager to pick out spots where in his opinion it is possible to examine different classes of merchandise properly. In the majority of cases points will be picked out illuminated with intensities twice as great as recommended by this Society, and often four times as great as that found where the goods are actually sold in that particular store.

High intensities permit a proper and speedy examination of merchandise, thus speeding up the operation of selling. Employes are enabled to find goods quickly; eye-strains and the accompanying headaches will be eliminated. An improvement in the esprit de corps and personal appearance of the employes is noticeable in those stores having the higher intensities.

The remedy for the present condition offers as great a field for the illuminating engineer as that which has been opened by one of the great western companies in industrial lighting. Executives should be impressed with the desirability of the proper intensities by demonstration on the part of the central station. Even though the central station is not generally engaged in the supply of electrical fixtures, an intelligent, constructive service forms an entering wedge whose value is unquestionable even though indeterminate.

A maintenance schedule providing for the cleaning of fixtures and replacing of lamps could be formulated for the store by the central station lighting service department or the lamp company's illuminating engineering division. The use of a portable vacuum

cleaner for cleaning fixtures has been successfully used in some cases, decreasing materially the maintenance labor costs.

Where stores persist in burning lamps longer than the recommended life, removal of such lamps to the floors say above the second, serves to maintain the illumination of the lower floors at a desirable intensity.

The use of a larger size lamp than would be used under normal conditions, serves a double purpose. By this means a high intensity is obtained with its resultant benefits. The maintenance schedule can be lessened considerably with a negligible loss in foot-candle intensities. Furthermore, it is often cheaper to pay for the increased current consumption than for the labor and lamps necessary to maintain a lighting installation with a small factor of economy.

This service should not stop at the manager's door. The chief engineer, the electrician, and their contractor should be painstakingly informed. Our motives in some cases will undoubtedly be questioned; but the results, even though slightly advantageous to those making suggestions, will benefit its followers many fold.

DISCUSSION.

This paper was discussed simultaneously with the preceding paper by Messrs. Hogue, Kirk and Tillson.

D. McF. Moore: Considering this excellent paper, together with the evident rapidly increasing use of the foot-candle meter, reminds me of a query I raised some fourteen years ago in our Society as to just how long it would be before the central station seriously undertook to furnish a definite amount of illumination, in other words, to sell lighting and illumination and not electrical energy.

There is every reason to believe that the tendency is in that direction, thus solving to a great extent, the matter of color and the matter of maintenance, and of course, intensity. The central station could propose to a department store, "We will furnish a definite amount per year; furnish a definite amount over this area at such a color and maintain it through the year."

Referring to Mr. Daniels' statement that it is almost unbelievable in this age that any store manager would question the desir-

ability of furnishing adequate illumination to permit a customer to examine his goods under the most favorable conditions, notwithstanding the fact that the average intensity of lighting in stores has increased ten-fold in something like ten years, it is to be noted that those of us who have had some experience in endeavoring to interest store managers a few years ago, in proper color-matching outfits, reached a point where we were not surprised when a manager's attitude indicated that he was not sure that he wished to show his customers goods under improved lighting conditions.

LOUIS BELL: The work that Mr. Daniels has been doing is the beginning of what should be a big drive for improved lighting of department stores using exactly the same process described in his paper, that of presenting the results of class surveys which have been conducted on a considerable scale. Such a plan has been made possible by the advent of the foot-candle meter, that being the only skirmishing instrument which has yet been provided, the only one with which one can walk up and down a floor and see at once just what conditions prevail. I have made tests in department stores and others, with all the available instruments recognized in the art, but haven't had previously anything to do skirmishing with.

It becomes possible now to conduct, on a large scale, class surveys for large stores and factories, throughout one or a dozen cities, and the effect of that kind of survey is going to be, I think, in every instance, just exactly what has been shown in this paper. The same thing should be done in the whole industrial field, and the final result in every case will be just as gratifying when the public becomes appreciative and begins to realize what it means, both from the practical standpoint of better lighting, and from the competitive standpoint.

No item in Mr. Daniels' paper impressed me more than that about the correlation of good lighting and good employees; reduced to the lowest terms, it means that a man who is slovenly in his lighting will stand for slovenliness in almost anything else.

NORMAN MACBETH: Mr. Daniels referred to the department store man who stated that he didn't believe in good lighting and

high intensities. I would not take that statement literally, because there are buyers who will take the other side of any argument in order to draw you out and note if your answers confirm their beliefs.

I recall an amusing instance of the bearing of one store on the lighting intensities of other nearby stores. A few years ago in a certain town up in New York State, the Woolworth Company had opened a new store, the scheme of store lighting having been planned at headquarters. When this store was opened, it appeared so brilliant by comparison that the other stores on the street were in comparative darkness. The central station man received many complaints from other merchants about the voltage, which on their line "must be low," and instead of grasping the opportunity of explaining the value of good lighting and boosting the lighting intensities in these stores up to the new standard, he was on the point of going over to the Woolworth manager to get him to reduce the intensity in the new store to the town's lower standard.

The comparison of one floor with another, rather than by departments, should not, in my opinion, be given undue weight. There are many stores where very low intensities are used in furniture departments, and where the intensities throughout the store are considered from the sales value viewpoint of the various departments. In one store in New York the windows of the furniture department face on the streets and yet the shades are kept down all day, such being the manager's idea of the proper light for selling furniture. Then, too, furniture is much more bulky than silks or wearing apparel, and it is not so easy to return if one finds it "looks different" when he gets it home.

G. B. Regar: Mr. Daniels has accomplished some splendid work from the standpoint of both the consumers and the central station, and I trust that he will continue his investigation. I believe that a distinction should be made as to classes of stores and, as to the various departments as Mr. Macbeth has mentioned.

The author has named five stores in Philadelphia; these are department stores in the true sense of the word, selling everything from automobiles to tooth picks and perhaps covering a ground area of approximately 80,000 sq. ft. The various intensities that he has given are an average for each floor, for instance

the second floor average for the first store is given as 5 foot-candles, whereas the measurements taken were as follows:

Children's wear	4 foot-candles
Linens	4 foot-candles
Men's clothing	7 foot-candles

It will be noted that the intensity on the fourth floor of this store is only 1.5 foot-candles, due to the fact that the measurement was taken in the summer in the rug department, during the off season. The decorators had put artificial flowers around the fixtures and cretonne covers over the lamps to produce an aesthetic effect.

I find that in the New York and Boston classification, some of the stores are hardly department stores, but are shops dealing in specialties, such as ladies' wear. Practically all of the smaller stores in Philadelphia are served by the central station, but of the five major department stores named in the paper, only the first two are served exclusively by the central station, the other three having their own plants with emergency central station service. It is to be noted that the former two stores have a higher lighting intensity than those having their own plants.

I have mentioned these facts only for the purpose of suggesting to Mr. Daniels the advisability of presenting his data in the departmental classification.

A. L. POWELL: I have had the good fortune for a number of yeast past to serve on the Lighting Sales Bureau of the National Electric Light Association. The aim of this organization is to present material outlining the best methods of selling lighting. As usual, the Illuminating Engineering Society has done the pioneer work, for these two papers tell the smaller central stations throughout the country how to sell store lighting. The practice recommended is based on sound engineering and a thoroughly comprehensive method of approaching the customer is outlined.

As in industrial lighting, there is also a necessity for standardization of store lighting equipment. This view may not be held by all engineers for on first thought individuality would appear to be lost. Careful analysis of the situation, however, indicates that there are three distinct classes of stores: the large department or

drygoods store, the lighting of which is handled by an engineer or the architect; the distinctive shop which requires elaborate special equipment of novel character, and third, the ordinary small store of which there are hundreds of thousands throughout the country. These last named like the small industrial plant, experience no demand for distinctive effects and might well be supplied with standardized equipment, embodying the best principles of lighting.

The central station manager in any community, I believe, should select two or possibly three standard units as the Commonwealth Edison Company has done. Salesmen can be trained to talk on the good qualities of these units, specialize on them and be in a position to outline intelligently the salient features of these particular equipments and explain why they best meet the illumination requirements.

JULIUS DANIELS: It would be interesting to know the effect of high intensity lighting in stores and how much to expect it to stimulate sales. There are so many variables that enter into consideration of this matter that it seems almost impossible to get comparative figures. We all know that there are surges in buying, a surge in the Spring and a surge in the Fall with a long valley in the Summer.

To arrive at a comparison of this kind, it would be necessary to compare the sales over an entire year with the same period when the lighting was of a different intensity. There are also many disturbing economic factors, such as depression in business, or strikes in the community that would have to be considered. During our attempts to obtain some such figures in Boston, the following incident arose:

Two of the largest stores in Boston both having practically the same type of building and employing the same grade of employees came under our observation. In one of these stores a large number of girls were found to be going home early in the day, due to headaches. Readings showed that this store was very poorly lighted, there being a low intensity and glaring light sources. The other store was very well lighted and although we could not get official figures for comparison we found there was approximately four times as many lay-offs, due to headaches, etc., in the store with the poor lighting as in the other.

G. H. STICKNEY: Eight or nine years ago I was associated with others in a rather thorough investigation of store lighting with the idea of standardization of the factor which we then thought could be standardized, especially the quantitative element. We made no foot-candle measurements but on surveying nearly 1,000 stores as to the quantity of energy consumed and the character of the lamps, and so on, it was possible to approximate the illumination. That investigation was presented to the Illuminating Engineering Society at the Niagara Falls meeting, in a paper by Messrs. Law and Powell. At that time, there was a criticism from central stations to the effect that we were going on the wrong basis, that we might ruin store lighting by a standardization that would make it uninteresting, that there wouldn't be any individuality left.

The little idea planted then has grown, and the data presented have been reproduced many times. The Commonwealth Edison Company and the Boston Edison Company have been leaders among the central stations in grasping these opportunities and carrying such investigations through on a larger scale than any other organizations that we have had the opportunity of working with. If we are to improve any class of lighting we should be armed with the best possible knowledge of existing practice, analyze it as to the strong and weak points, and then prescribe or recommend such modifications as will meet not only present needs, but those of the near future so far as the indications of progress will permit.

Store lighting responds to such treatment more readily than almost any other application of artificial light. The simpler the treatment the more readily it is appreciated, and hence the wattage basis is often desirable as representation of the light quantity.

F. C. CALDWELL: I wonder if it is generally appreciated that if a central station company "sells" its product at all it necessarily sells light, power or heat. The central station salesman cannot very well go to a prospective customer and expect to sell electrical energy by telling him what fine electricity it is and urging him to buy more on that ground. It is some way of using the energy that must be sold, and it is very good to find that the central stations

are really coming to appreciate this fact as far as light is concerned.

Mr. Moore spoke of having urged the importance of central stations selling light as expressed in foot-candles. A few months ago, one of the big lamp companies had a request for an estimate on so many foot-candles to be provided throughout a certain factory, which shows that the idea of buying foot-candles rather than buying watts is taking hold of the customer.

J. B. KELLEY: Since becoming associated with the lighting fixture dealers, I have found it a very delightful experience to talk to them about illuminating engineering. They are in that quiescent state of thinking of illuminating engineering with a feeling of awe that it is a subject far too big for them to approach. It seems to me that the Illuminating Engineering Society can do no better work in raising the standard of illumination and the standard of fixture design than by getting in personal contact with the lighting fixture organizations which have become well organized throughout the United States, particularly in the Middle West. Cleveland is probably the best organized city I know from the standpoint of lighting fixture dealers.

Our concern insists first, on proper illumination; second, on proper color, and third, on proper design, and last of all gives consideration to the cost of the fixture and cost of energy. We find that the department store manager is willing to listen if the matter is brought to him in the proper manner, the proposition being presented from the standpoint of his convenience, not expense, not advertising, but an investment at a cost of so much as compared with his other investments.

A. F. WAKEFIELD: From the standpoint of a manufacturer of lighting fixtures the advantage gained from the connection with the Illuminating Engineering Society is not always striking, but I am sure that the presentation of such papers as those by Messrs. Hogue, Kirk and Tillson and Daniels is bound to make apparent certain advantages.

The position of the manufacturers in regard to commercial lighting partakes of the nature of standardization. They have watched the development of commercial lighting very closely, and

concluded that the totally enclosed unit carries out best the recommendations of the lighting engineers, and they have gone so far as to standardize on the hanging tackle for this nature of unit.

JULIUS DANIELS: Readings necessary to make the comparison presented in my paper were not at all easy to obtain. At first, a number of managers were suspicious of our request, but after the plan had been explained to them they were glad to allow us to obtain the desired information.

In one case where at first objection was raised by the engineer to the taking of such readings, the management not only gladly gave us permission to take them but offered to pay us for doing so.

The figures as given are, by no means, exact but are close enough for the purpose of comparison. An attempt has been made to give figures which can be placed before the department store men to serve as a basis for further investigation on their part.

I wish to thank Messrs. Regar and Law for their assistance in obtaining readings in stores in their respective cities.

BRIGHTNESS—I.*

BY BASSETT JONES.

INTRODUCTION.

This paper resulted from certain difficulties of understanding in connection with the problems of illumination, that I first encountered when reading Dr. H. E. Ives' little paper "The Measurement of Brightness and Its Significance" published in 1915.[1] An apparent inconsistency of the conclusions as to the nature of brightness previously reached subsequent to a reading of William James "Psychology", with certain statements in Dr. Ives' paper, lead to a rather careful study of most of the available literature in English on the psychology of vision. This resulted in a conviction that the psychological aspect of illumination was as important to a proper understanding of its manifest and numerous unsettled problems, as an understanding of its physical aspect. I am satisfied that the future development of illuminating engineering hinges on a linkage between the psychology and the physics of vision and, if I may now state the conclusion I wish you to draw from my paper, it is that in illumination, psychology must dictate to physics.

The first notes and studies for this paper were written in 1915, and so as to take account of the recent work of Ferree and Rand, Nutting and others besides Ives, all of whom have done so much to put the practice of illumination on a proper basis, have been revised and more or less continuously subjected to criticism from that time to this.

With the publication by Nutting of the general differential equation of brightness reaction which proved to be unsolvable, I felt that the limit of physical and physiological methods had been reached, and that a restatement of fundamentals was necessary.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] TRANS. I. E. S., Vol. IX, No. 3.

The results of this study of fundamentals are not presented with any idea of finality, but merely with the thought in mind that they require discussion, and may give you a point of view that has been of great help to me in my practice of illumination. That illuminating engineers are feeling uneasy as to the validity of present methods is evident from the appeal sent out by our Papers Committee for a discussion of the Unknowns of Illuminating Engineering. If you like, you may look upon this paper, as representing my contribution to that discussion.

You will learn that certain things we have all regarded as fairly well determined, I have found to be real problems. Whether or not my findings are sound in reason, remains for you to decide. I do not claim that all causes for the frequently vehement criticism by my trial readers has been removed. On the contrary my reaction has been to emphasize the points of disagreement, perhaps to excess. My excuse is that with some of my critics opposition on fundamental grounds has thus been converted to doubt and, in some cases, to at least tentative agreement.

If you do not like them, please overlook the introduction into the discussion of certain rather metaphysical topics. Language is a very inadequate vehicle for ideas, and most discussions originate in the absence of mutual understanding. In these little side notes I have attempted to fit you to the same mental filter I use myself. As Max Müller says in the Preface to his translation of the "Critique of Pure Reason", "the discoveries of physical observers, if they are to be more than merely contingent truths, must find their appointed place and natural refuge within the limits traced by the metaphysician," the metaphysician being one who seeks to establish the nature of understanding and trace its limits or its scope.

In this paper I do not intend, nor do I wish, to prove that the methods of illuminating engineering are essentially wrong. I merely desire to show that the foundations of such methods as in all other realms of physics, are contingent truths, and that it may be necessary to somewhat alter our definitions so as to bring forward and keep in mind certain psychological aspects of our problems.

I. THE FUNDAMENTAL OF ILLUMINATING ENGINEERING.

A Question.—The thesis of this paper can be put before you in the form of the following question: Does brightness exist whether or not an observer is present? Or, again, and less abstractly: Is the wall of this room bright if no one is here to see it? Suppose we go out and shut the door, is there *then* any brightness in the room?

The answer you give to this question will depend on whether you habitually conceive brightness to be a function of luminous objects, or a function of the observer's visual experience of such objects. In other words, your answer will depend on whether you conceive the brightness of the wall of this room, or the brightness of the paper of this page to be essentially an independent *physical* property of the wall or paper, or, on the other hand, whether you conceive this brightness to depend essentially on your *experience* of the luminous properties of such objects. Thus, your acceptance or rejection of any particular definition of brightness, will be largely controlled by your mental habits or convictions. If you have never thought of brightness in any other way than as a sort of potential visibility belonging to luminous objects, it may be very difficult for you to admit that any other conception of its nature has the slightest claim on your attention.

An idea, or a conception, novel to any particular structure of understanding we call an individual mind, simply cannot pass the mental sieve. It is rejected automatically as unfit or unsound. Its presence, like sand and in the gear box, produces mental friction and discomfort. In this way ideas are "tagged" by the individual as reasonable or unreasonable. Those of us who, through heredity and association respectively, possess more or less similar and common mental structures, form a mental group. If the members of such a group concur in the acceptance or rejection of an idea, then it is tagged by the group concerned, as respectively true or false.[2] In so far as our minds are alike they possess a logical form.

Instantaneous and instinctive rejection of an idea implies impact. Mental impact suggests mental sclorosis. Generally it is a

[2] This definition of truth is admirably set forth in "Thought and Things," J. M. Baldwin, Vol. II, Chs. III and XIII, also in "William James and Other Essays," Josiah Royce.

sign of decrepitude. So before we accept or reject one or the other conceptions of the nature of brightness it may be well to determine just what we mean by the term. Naturally you will ask, what possible practical difference will result whether we think of brightness as a physical property of the luminous object or as a function of our visual experience. This is precisely the question I intend to discuss, and I hope to show that there results from the answer to this question, a decided practical difference in the way we approach and solve any problem in lighting. The entailed difference in viewpoint leads to an important difference in practice.

Subjective and Objective Brightness.—Remembering what has been said above regarding acceptance and rejection of ideas, let us recall that psychologists have used the term "brightness" as a name for one of the two characters of visual sensation—the other being color. To the like minded group called "psychologists", the term "brightness" does *not* immediately convey an idea of a physical property of luminous objects. To use it in any such sense would create in their minds something approaching mental havoc. The psychologist would ask "How is it possible for brightness to be a physical property of external bodies, when we know is is primarily subjective ?" He would argue somewhat in this fashion: "We *perceive* the object to be bright. Its brightness is entirely a matter of our visual experience." "To conceive brightness as primarily physical is to reverse the order of the actual sequence of events. There is no brightness until physical energy radiation has been received on the retina and *there* converted into nerve activity which, in its turn, arouses in the mind the sensation of brightness. *Then,* and not before, we see the object as bright." "Seeing, is a motor reaction to the unseen physical stimulus, and gives rise to the sensing of the object as externally or objectively bright. The objective brightness is the *result* of the stimulus, not the stimulus itself."

Let me quote somewhat disconnectedly from Judd.[3] "A visual sensation is a fundamental element of experience which arises in consciousness under certain conditions of retinal stimulation. This stimulation is induced by the action of certain external

[3] "General Introduction to Psychology", C. H. Judd. The Visual Sensations: p. 73.

physical activities." "The sensation is a conscious fact depending quite as much on the existence of a conscious being as on the existence of physical light or retinal processes." "The laws of brightness and color are primarily laws of retinal behaviour rather than laws of the physical world."

It is not necessary to add authority to authority to show that the psychologist thinks of brightness as essentially a mental phenomena. Objective brightness results from the act of seeing. It is "projected" to the source of the stimulus as a response that completes the cycle of reality.[4] If the word "objective" means anything, it means the end of action rather than its beginning.

On the other hand, we, as engineers, have learned to think of brightness as something originating at the object and therefore essentially physical. This we have called "objective brightness", in consequence of which subjective, or "apparent," brightness results to us from a rather blurred and defective mirror-like action of the mind. It is this "outer" brightness that seems "real" and fixed. Therefore it is something that we can divide and multiply, for only those things are *real* to us that reasonably submit to mathematical laws[5] and can be measured.[6] The "brightness" of the psychologists nomenclature has every aspect of mystery that we instinctively associate with the things we do not understand.

Is it that these two widely different viewpoints have arisen because we are using the same name for different phenomena ?

This may be so if by "objective brightness", the nomenclature of illuminating engineering means the stimulus of the brightness sensation. But the stimulus is not brightness but physical energy flux. The objective brightness, in the correct use of the term, is subsequent to the stimulation and coincident with perception of the sensation of brightness. It is the production of this sort of objective brightness that is the proper aim of illuminating engineering, and, since objective brightness depends on brightness sensation, the technique of the art should consist in producing the

[4] Indeed, only as the things of the outer world become objective in this sense, do they have any meaning, any value, and in the last analysis, any reality. *Vide*, J. M. Baldwin, "Genetic Logic," Vol. I, p. 37.

[5] By *mathematical laws* I mean the laws of logical implication. See Bertrand Russell, "Principles of Mathematics," Vol. I, Ch. I. By specialized training and environment the engineer and the scientist, quite commonly, have acquired a judgment almost exclusively of the implicative type.

[6] As illustrated by Planck's famous dictum, "whatever can be measured is real."

necessary brightness sensation when using the minimum possible amount of radiant energy.

This, it seems to me, is not the way the art is tending. Apparently the illuminating engineer is imbued with the idea of physical brightness and this idea controls his attitude toward every lighting problem.

Brightness Definable Only in Terms of Visual Sensation.—In his paper on Apparent Brightness,[7] L. T. Troland attempts to harmonize these two viewpoints as to the nature of objective brightness. He distinguishes brightness as visual sensation by the term "apparent brightness". He says "By apparent brightness is meant the brightness of any object of vision exactly as it *appears* to a given observer. This quantity is often called brightness sensation; but the term is somewhat misleading because luminosity is a property of external objects as *we see them*." This distinction between the brightness of an object apparent to the observer and the brightness of the object not apparent to the observer I must confess is not "apparent" to my mind. I can no more conceive of a brightness that is not seen than I can conceive of a musical note that is not heard, or feeling that is not felt. Thus I confess to a predisposition for the psychological attitude toward this problem.

In the above quotation from Dr. Troland's paper I have italicised the words *"as we see them"* because, if I understand their meaning aright, they infer a definition of luminosity in terms of seeing, and thus draw a distinction between brightness as an independent outer physical property of light radiating bodies and the luminosity of such bodies, which is the way they look "as we see them". In other words, when the observer sees the object, its brightness is somehow translated into luminosity. Brightness is then to be considered as an inherent character of such objects. As such, it must be defined only in terms of physical states of the object, which is a logical impossibility. Indeed, from this angle of view, brightness must remain forever masked by a curtain of appearances—a logical wraith of an intensely real and living quality of our visual experience.

The argument put forward in the present paper goes the other way around, and begins at the opposite end of the diameter.

[7] TRANS. I. E. S., Vol. XI, No. 9.

Apparently Dr. Troland starts at the object whose brightness is assumed as given and ends with an appearance in the observer —the typical argument of realism so successfully annihilated by Bradley.[8] Here we shall start with the perfectly obvious fact—not an appearance—that light radiating objects are bright when we see them and thus get a sensation of brightness. This brightness is the result in consciousness of stimulation by purely physical activities. We shall therefore end with an appearance of brightness at the object, not in the observer. Evidently the object is bright when we see it. Why then assume there is anything else to its brightness ? Or, if this be no assumption, how shall we prove its truth ?

The mode of analysis proposed seems to be quite in accord with the observable cycle of events.

Psychologically speaking, brightness, sound, feeling are mental activities aroused by physical stimuli. The stimuli are quite different things from the sensations they arouse—as different as the ripple on the pool and the breeze that produces the ripple. There may be a definite quantitative, or even only qualitative, link between them, but this does not make them even of the same order of phenomena.

Should one be struck by a stream of water from a hose, would it be logical to say that the feeling of wetness and the feeling of pressure produced were only apparent, and that the objective feelings are properties of the external hose nozzle ?

Is the feeling of warmth experienced from an open fire merely "apparent ?" Is there any such thing as objective warmth resident in the blazing log ? No, because the feeling of warmth, like brightness, is a sensation.

I hope that the point of this discussion is clear, for, as I shall now attempt to show, no *reasonable* definition of brightness can be given except in terms of visual sensation. I say reasonable, because it is proper to assume that the definition of any term contains no other than terms in the same class to which the defined term belongs. It therefore is a term in an ordered series of terms, any one of which may be deduced by logical processes from other terms in the same class. The cat may be defined in terms of lions by stating that the cat belongs to the same family

[8] F. H. Bradley, "Appearance and Reality."

to which the lion also belongs. But the cat may not be defined in terms of oysters unless we allow that, in some fashion, oysters and cats belong to the same extended class to which cats and lions belong. This statement may seem unnecessary; yet it is remarkable how frequently we fail to adhere to the rule of reason thus illustrated in a purposely irrelevant case.

I think it has been shown above that brightness sensation and objective brightness, using the word "objective" in its proper sense, are of the same class; for the one is subjective in relation to consciousness, the other objective to the same consciousness. Both originate in consciousness and cease with consciousness. Apart from consciousness they have no existence.

Brightness conceived as a purely physical character of radiating bodies and entirely independent of consciousness is, necessarily, of another class than either brightness sensation or objective brightness. The being, or not being of a conscious observer can have no effect on it whatever, any more than his observation would have a necessary effect on the electric charge on a conductor. Therefore, we must define this sort of brightness with no reference to the observers' existence. And, how shall we do so? For myself, I am entirely at a loss to devise such a definition. Our nomenclature defines "objective" brightness as the normal component of luminous flux per unit area of a luminous surface, and by "objective" brightness is here meant a "physical character of the luminous surface independent of the presence of an observer." This is, of course, a wrong use of the word "objective." The definition seeks to describe the nature of physical brightness—if, logically, such there be. But in this definition the work "luminous" occurs. What is its meaning? It means, I take it, that this unit area possesses the power of producing in an observer the sensation of brightness. It possesses this power whether the oberver be present or not, but this potential fact is not the fact itself, any more than the electric potential between two points in space is the same as the current that would flow between them were they connected by a conductor, and, in this analogy, there is also the resistance to consider. Of course we may define brightness as this sort of potential luminosity if we please, but this device does not get rid of the observer. *He* defines the potential! A luminous surface is one that emits

visible light; and how visible shall it be? If it be all at $\lambda = 0.700\ \mu$, it will be hardly visible; and so the surface will not be bright. If it be all at $\lambda = 0.545\ \mu$, it may be highly visible and the surface may seem very bright indeed. There is, therefore, a considerable difference in this physical "brightness" of the surface, depending on how visible is its radiation, and visibility means the amount of brightness sensation that can be aroused in the observer's eye. So the ubiquitous observer again bobs into view. We simply cannot get rid of him, and since we cannot omit him, we must define his ability to have brightness sensation, for upon this obviously depends the so-called physical brightness of the radiator. We already know that its objective brightness will be the result of the brightness sensation so produced.

This quite futile dodging of the observer can get us nowhere and I propose to end the discussion by taking him into the definition and making him the center of it. Let us say that the objective brightness of a luminous surface is what it seems to an observer. The related physical character of the surface, independent of the observer, is that it emits radiant energy of a certain spectral distribution of energy intensity. This character of the radiation is definable and determinable independently of the observer's ocular peculiarities, but the relation between intensity of physical radiation and objective brightness is determined by the observer's eye. All we shall say about it at present is that physical energy radiation of suitable character and intensity, *when* incident on the retina of the observer's eye, through certain physiological activities thereby aroused, produces a certain brightness sensation. This brightness sensation results in an appearance of brightness *at* the object which we shall here call its objective brightness.

The attempt to bolster up the physical definition of brightness by introducing in place of the feeling observer, a proposed physical instrument of measurement such as the photo-electric cell, merely forges another link in the chain. For the definition of the sensitiveness of such an instrument, if it has any bearing on illumination, must be given in terms of the observer's eye. If such an instrument does not measure intensity of physical radiation as the observer would measure it in terms of brightness sensation, the instrument is useless as an agent for physical photometry.

I conceive this relationship between energy stimulus and brightness to be somewhat analogous to the relation between current density in a resistance shunt, and milli-voltmeter indication of the current flowing in the electric circuit. The physical stimulus is the current, the ammeter shunt is the sensitive organ, the current in the instrument leads is result of stimulation controlled by conductivity of the shunt, which corresponds to retinal sensitivity. The instrument registers the result of stimulation in the form of angular deflection of the needle. This deflection corresponds to intensity of brightness sensation. The sensitivity of the instrument itself corresponds to mental conditions controlling the degree to which the sensation becomes conscious.[9] The scale is omitted from the instrument for the obvious reason that the eye has no scale of brightness.

The analogy would fit the case better if the sensitivity characteristics of the shunt and instrument were interchanged, or, for instance, if a shunt of large temperature coefficient were used. At any rate, the eye thus acts as a measuring instrument without a scale, having a sensitivity varying widely with the stimulus. It measures the intensity of radiant energy incident on the retina as stimulus in terms of intensity of brightness sensation. Due to the varying sensitivity of the eye, the magnitude of the sensation is not directly proportional to the stimulus.

Let us now add one complication to this analogy by placing a mirror on the source of current, and by arranging the instrument so that the observer notes the needle deflection by reflection from the mirror. The deflection then *seems* to be *at* the source.. In so far as it corresponds to objective brightness. Of course, I realize that this last device stretches the analogy beyond its elastic limit. Physical analogies of mental processes are apt to be very misleading. However, it may serve to visualize the general attitude toward the problem of brightness set forth in this paper, for the reader who has had neither time, opportunity nor inclination to study the psychological aspects of illumination.

A Definition of Brightness is the Fundamental Postulate of Illuminating Engineering.—So far the discussion has centered about two existing definitions of brightness, the one an attempt

[9] M. Meyer, "The Nervous Correlate of Attention," *Psychological Review*, Vol. XV, No. 6.

to limit the definition to physical terms, the other given purely in sensory terms. I have sought to show that the physical definition breaks down because of the necessary introduction into it of sensory terms. The physical definition is therefore not fundamental, and a theory and practice built upon it is likely to become inconsistent in development and lead to incorrect results. This I believe, is exactly what is happening or has happened in the practice of illuminating engineering. Through the use of a wrong postulate, we have been led up a blind alley.

Thus, our nomenclature presents us with such terms as "flux density," flux being a rate of flow; the rate of flow across a unit area perpendicular to the stream lines at every point defines the flux density. So we arrive at "lumens per square foot" or "lumens per square meter," as the case may be. This is all in strict accord with physical nomenclature. For instance, there is the rate of flow, or flux, of electricity across unit area of the conductor, or the total current in the conductor divided by the cross-sectional area of the conductor, giving current density.

My argument has its roots in the point of view that we have permitted this undoubtedly useful analogy between the character of brightness relations and energy relations to lead us into the untenable position of conceiving brightness as a physical entity in the same sense that current density and electric potential are physical entities. I believe that this analogy, like all such analogies, fails when carried too far, and so leads to a confusion of the logical mental picture or conception upon which the development of the art is built.

We conceive of the candle or unit of luminous intensity as strictly analogous to flux intensity. Mathematically, this may be true because our postulate that this analogy is an equivalent leads to consistent mathematical implications. As I see it, the difficulty is that the implications of the postulate as to the physical nature of brightness, while they may be consistent with themselves are not consistent with visual experience. My proposal is to start with visual experience and reason from this outward to the physics of our problem. I believe that when we do this the inconsistencies disappear.

Perhaps it is unnecessary to show that a statement of the nature of brightness is necessarily the fundamental postulate at the foun-

dation of scientific illumination. That such is the case seems obvious, because all the illuminating engineer does is produce arrangements of brightness. In the paper above quoted (p. 948) Dr. Troland points out that in the last analysis it is not radiation, but what we have here called objective brightness that it is the function of illuminating technology to create.

As we have seen, objective brightness results from the intensity of brightness sensation. It is brightness the eye sees, not lumens or foot-candles. Some years ago Dr. H. E. Ives, in a paper called "The Measure of Brightness and Its Significance," in effect stated that "the art of good lighting is the art of the proper distribution of brightness." This statement is, I think, the key to the whole problem; but apparently it has passed almost without notice. In his remarkable papers, "Energy Standards of Luminous Intensity,"[10] and "Luminous Efficiencies,"[11] by the closest margin, Dr. Ives fails to draw the deduction that brightness sensation is the measure of luminous efficiency. He actually shows that such is the case but for some unaccountable reason or probably because of his mental habits, in his paper, "The Measurement of Brightness and Its Significance,"[12] he draws the conclusion that "brightness is a physical character of the light giving surface," a conclusion totally at variance, it seems to me, with his experimental facts.

The work of Dr. P. G. Nutting has quite the same tendency as that of Dr. Ives, but his conclusions, probably for the same reasons, do not come to a head in any specific statement that indicates on his part any conception that brightness is not a physical phenomena. He rests his case in demonstrating that the intensity of brightness sensation is a very complicated function of retinal behavior.

II. THE MEASURE OF BRIGHTNESS.

The Ratios of Conversion.—In this cycle beginning with radiation intensity at the source and extending through radiation intensity at the retina and physiological behavior of the retina, to intensity of brightness sensation, and thus back to objective brightness at the source, there are two relations that must be

[10] TRANS. I. E. S., Vol. VI, No. 4.
[11] TRANS. I. E. S., Vol. V, No. 2.
[12] TRANS. I. E. S., Vol. IX, No. 3.

defined if we are to reduce our problem to a basis of measurement. The first of these is the ratio between intensity of radiation at the retina and brightness sensation via intensity of physiological activity in the retina. The second is the ratio between intensity of brightness sensation and the objective brightness of the source.

The Ratio of Stimulus Intensity to Intensity of Brightness Sensation.—There are two ways in which a determination of the first of these ratios can be made. First, by finding the ratio between the intensity of the incident energy as a whole at the retinal image to the intensity of brightness sensation produced on an arbitrary numerical scale of brightness. The unit of the scale being the intensity of brightness sensation produced by a source subtending a desirable solid angle at the plane of a pupil of fixed area under suitable surrounding field conditions establishing determined retinal sensitivity; the source emitting radiation according to Lambert's Law, of known spectral characteristics and intensity. For the optical system defined by the eye, the intensity of incident energy at the retinal image will be the same as the intensity of emission by the source less intervening losses by scattering or absorption. This method is the most useful for practical purposes, but it defines the ratio in terms of radiation having one and only one spectral characteristic. As long as the spectral character of the radiation emitted by any source used in practice does not depart widely from that of the standard used in determining the unit of brightness, the method will give fairly consistent results. The method leads exactly, to a different scale of brightness for each spectral distribution of radiation intensity. It is a rather neat case of relativity. It is not the absolute magnitude of the sensation intensity that changes, but the scale of measurement. According to our hypothesis the same sensation intensity must be the same regardless of the spectral co-ordinates in which it is measured, but any variation in co-ordinates leads to a different reference system. It is necessarily impossible that we should be able to compare brightnesses of different spectral composition. Hence the problems of hetero-chromatic photometry.

The second method of determining this ratio is to compare energy intensity and intensity of brightness sensation separately in each set of spectral co-ordinates, or wave length by wave

length. The only determination by this method that has been made, is for purely "cone vision" in the average eye, and is set forth in the so called "visibility data." It gives the relative intensity of brightness sensation aroused by a constant intensity of radiant energy at various wave lengths when received on a fixed retinal area held at constant sensitivity. As pointed out by Dr. Troland, the results, when corrected for selective absorption of the eye, plot as a very close approximation to the "probability curve", with its maximum about in the center of the range of visible wave lengths.

This curve Fig. 1., is plotted in $\frac{\text{per cent.}}{100}$ of its maximum. It thus gives the relative intensity of sensation (response) produced by any given intensity of incident radiant energy stimulus

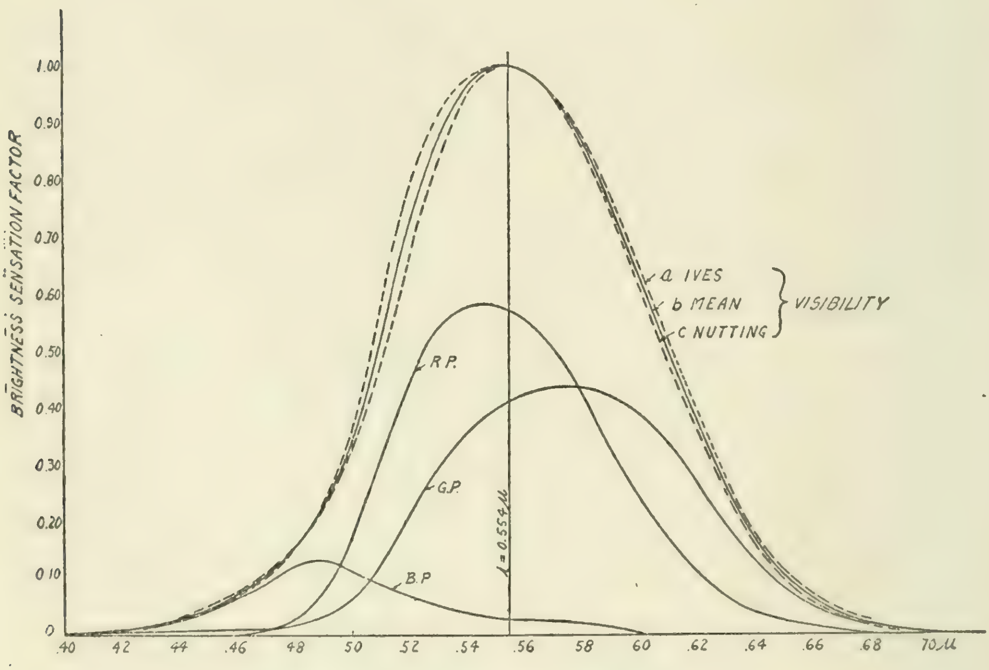


Fig. 1.—Brightness sensation factor.

at any single wave length, in terms of the intensity of sensation produced by the same intensity of radiant energy at the particular wave length resulting in maximum intensity of sensation, $\lambda = 0.545\ \mu$.

Therefore, in any particular case of spectral distribution of energy intensity, if the values of energy intensity, at every wave

length be multiplied by the corresponding factor in $\frac{\text{per cent.}}{100}$ taken from the visibility curve, a curve results whose ordinates are presumably in proportion to the sensation intensity produced by the energy intensity in case. This resulting curve is known as the Luminosity Curve for the corresponding distribution of energy intensity. If, by actual measurement, the sensory value of any unit of energy intensity at any wave length is known, then the Luminosity Curve for any distribution of energy intensity can be converted into a curve giving the actual quantitative distribution of intensity of brightness sensation for any quantitative spectral distribution of energy intensity. No such measurement being possible, luminosity curves remain purely relative in value. A group of such curves for various forms of energy distribution is given in Fig. 2. The energy intensity is assumed equal for all distributions at $\lambda = 0.545\ \mu$. The ratio between energy intensity and sensation intensity at $\lambda = 0.545\ \mu$ is arbitrarily made equal to unity.

The mean ordinate of each luminosity curve is assumed to be proportional to the intensity of sensation aroused by all the energy received simultaneously on the fixed retinal area used in determining the visibility data. This assumption involves what we shall later discuss as the *Theorem of Brightness Summation*. The mean ordinate of the curve of energy distribution is, in each case, proportional to the intensity of the incident energy on the retina when reduced by the selective transmission factor of the eye; or the visibility data may be reduced by such factor so as to apply directly to the energy distribution as measured by a bolometer or equivalent device.

The ratios of these relative intensities for each pair of related energy and luminosity curves are proportional to the first ratio in the preceding discussion of the brightness cycle for the particular arrangement and history of retinal stimulation used in determining the visibitity data for the so-called "average eye". Only that part of the energy distribution lying between the limits of visibility is used in determining the intensity of incident energy, as energy outside these limits plays no apparent part in producing brightness sensation.

The mean ordinates of any such luminosity curves are proportional to the objective brightness of the sources used when viewed

under the same conditions employed in determining the visibility data.

It is necessary to restrict this determination to a fixed set of conditions, for as has been shown, both by Ives and by Nutting, the intensity of brightness sensation aroused by any given intensity of radiation depends not only on the previous history of the

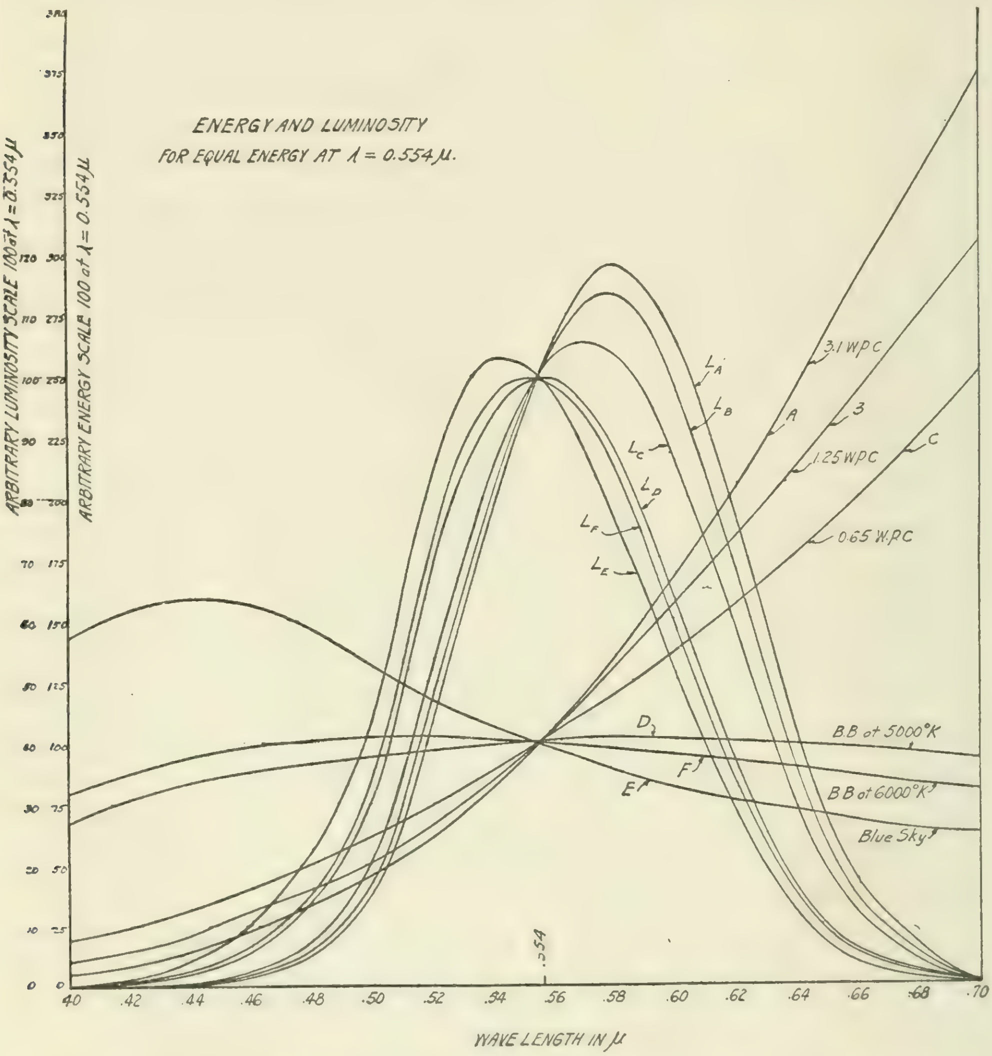


Fig. 2.—Energy and luminosity curves.

retina (adaptation, etc.) but also on the intensity distribution of the incident radiant energy over the retina (intensity level, intensity contrast, etc.) as well as upon its spectral distribution (color).

Under different optical and ocular conditions, the same quantity and spectral distribution of energy results in different visibility data and, therefore, in different luminosity. Consequently the

source will differ correspondingly in objective brightness. Indeed, since the average visibility data graphed in Fig. 1 is determined under certain quantitative conditions as to energy distribution desirable from the viewpoint of accuracy in measurement, we cannot assume that it is applicable to other distributions in which the intensity at any wave length varies materially from the intensity at the same wave length used in the primary determination. Therefore even the results obtained in Fig. 2 are based on an assumption of generality which may not be altogether true.

It is known, for instance, that at lower stimulus intensity the maximum of the visibility curve tends to shift toward the blue end of the spectrum when the determination is by the equality of brightness method, and toward the red end when the determination is by the flicker method. There is also evidence that a change in the size of the field causes a change in the visibiltiy data. A decrease in the size of the field appears to shift the maximum toward the red with the equality of brightness method and toward the blue with the flicker method.[13 14] These changes probably correspond to changes in retinal sensitivity with variations in field arrangement and stimulus intensity, For, after all, the visibility data itself, merely tells the story of the selective sensitivity of a determined portion of the retina to a given intensity of radiant energy at various wave lengths or periodicities. Every such change in field condition means a change in retinal sensitivity and, therefore, a change in the objective brightness of the source.[15]

Whether or not the visibility curve as now determined does express a fact applicable to the general problems of illuminating engineering, the graphic results thus obtained may be used as a means of visualizing what, at least, are the general magnitudes and relations of brightness phenomena. The phenomena in question are actual. The eye does translate intensity of incident luminous energy into intensity of brightness sensation. The given curve of luminosity merely presents the relation between the two for one particular case. Whatever quantitative value this relation between any such pair may have, the mean ordinate of the corresponding luminosity curve is the objective brightness of the source of luminous energy. Whenever a reading is made on a

[13] Ives, "Some Spectral Luminosity Curves," TRANS. I. E. S., Vol. V, No. 8, p. 717.

[14] Nutting, "The Visibility of Radiation," TRANS. I. E. S., Vol. IX, No. 7, p. 633.

photometer, the instrument relates two objective brightnesses for an individual observer on an arbitrary scale of ratios, by equalizing, so to speak, the mean ordinates of the luminosity curves as averaged by the particular observer's eye; the luminosity curves in question representing graphically the luminous value of the radiation intensity incident on the two parts of the retinal image of the photometer field.

From the above it is obvious that radiant energy confined to that part of the spectrum for which the visibility data is a maximum will produce the maximum brightness sensation for a given amount of radiated power and for a given retinal sensitivity. Furthermore it is fairly well established that visual acuity is heightened by the use of nearly monochromatic illumination, so it is logical to conclude on this basis that, leaving out question of color discrimination, such light should prove of the highest visual efficiency. But logic is merely a method of reasoning from premise to conclusion. Given the premise the conclusion, as in legal or mathematical formulae, must follow and is valid. The question as to the truth of either premise or conclusion does not enter essentially into the case, until both are shown to correspond always with our common experience.

Before we can accept any such deduction as to the visual efficiency of any particular character of radiant energy, it must be shown that no effects other than immediate visibility and acuity control the proper functioning of the retina. It is well known,

[15] Several attempts have been made to assign a reason for the particular form of the visibility curve related to the form of energy distribution in the sun's spectrum. Here again it seems to me the natural tendency of physicists to look outward and seek only for causes among physical phenomena has led them astray. A study of the development of the color sense during the early stages of mental devlopment in the child has shown that apparently the infant first develops a sense for the color of objects in the yellow-green or near the middle of the spectrum, next for blue and last for red. See: J. Mark Baldwin, "Mental Development in the Child and the Race," pp. 37, 48. The results obtained by the writer over the first year period from his first born child follow very closely the results obtained by both Baldwin and Shinn. The sense for red being therefore of recent origin in the evolution of the color sense retains its novelty and in noticeable amount is a source of mental excitement. These stages in ocular evolution are assigned by psychologists not directly to the distribution of energy in the sun's spectrum, but to the distribution of energy in the light reflected by or transmitted through the environment. Probably in the fish age of organic evolution the general hue of the environment was a yellowish green. Of course, this fundamental natural basis of selective visibility is overlaid in later life by an immense complication of selective effects—environmental, adaptation, sexual, and aesthetic. See Grant Allen, "The Color Sense," and Bain, "The Senses and the Intellect," pp. 226-230.

for instance, that both brightness and color sensitiveness of the eye are very variable among individuals, and even in the life of any one individual. Both are subject to rapid adaptation in response to the environment and to volition. Therefore, we are justified in asking, among other questions, does the prolonged subjection of the retina to radiant energy of any particular spectral distribution of intensity widely different from that for which the retinal function has been primarily adapted, have any deleterious effect on the general usefullness of the eye. This and similar questions, I have never even seen discussed by illuminating engineers. They are almost moral questions. For have we any right to argue from any such insufficient data, that for the sake of increased production, for instance, we shall subject workers eyes to conditions that may insidiously destroy or warp certain other and, from the viewpoint of the workers life, even more important visual and allied functions. Much time and thought has been given to the deleterious effects of prolonged improper intensity distribution over the retinal field, but apparently none to the effects of prolonged subjection of the retina to various spectral compositions of this intensity. There is much food for thought on this subject to be found in Woodruff's "Medical Ethnology".

Radiant energy in the longest visible periodicities alone is a stimulant of nervous excitement. Mixed with radiant energy in the shortest visible periodicities it becomes almost a positive irritant. Is a normal amount of red as a stimulant to nervous response necessary in continued vision? Is the entire lack of it a cause of relaxation, and, eventually, of depression? These are questions that can only be answered definitely by the methods of the psychological laboratory—the measure of nerve currents by the string galvanometer, blood pressure tests and the like, which remove the results obtained from control by the personal judgment of the test subject. It is possible that such ordinary galvanometric methods as used by Boris Sidis and Kalmus in studying physio-psychological processes may answer the purpose.[16, 17]

[16] Sidis and Kalmus, "A Study of Galvanometric Deflections due to Psycho-Physiological Processes," *Psychological Review*, Vol. XV, No. 6, and Vol. XVI, No. 1.

[17] Boris Sidis, "The Nature and Causation of Galvanometric Phenomena," *Psychological Review*, Vol. XVII, No. 2.

Recently the writer tried the following experiment suggested by certain of Woodruff's conclusions. Two adjacent office rooms with connecting door were given different color treatment both in paint and light. One room was given the commonly used ordinary buff wall color, with white ceiling and was lighted by type "C" lamps in "semi-indirect" fixtures showing, on the photometric scale, a brightness of about one candle per square inch. The walls of the second room were treated with a specially prepared soft and pale gray olive green, mixed of all the pure pigment colors in about the proportion of the ordinates of the visibility curve and desaturated with lithopone. Again the ceiling was white, but C-2 lamps were used in the fixtures. The mean photometric brightness in both rooms was about the same. On the brightness scale of the unassisted eye, the second of the two rooms was commonly judged to be much the least bright of the two; but there was complete unanimity of opinion on the part of those who had been using and continued to use both rooms, as well as on the part of those who had occasion to spend even a short time in both rooms, that the second room was much the most restful, and that better discrimination obtained in it. Indeed by contrast the first room was distinctly irritating, and also, by contrast, its color was markedly red.

Now this irritation had not been noticed before, yet undoubtedly it was present, and because habitual, in an unconscious state. Undoubtedly it acted to reduce mental efficiency.

Such marked evidence of general fatigue caused by a not very wide deviation in the spectral character of the field of view should bid us hesitate before we assume that the spectral character of the field is not of importance equal to that of brightness distribution.

Successful repetitions of the above treatment of interiors has convinced the writer of the reasonableness of his conclusions. Truth has been added by the concurrence of every worker who has been called upon to try out such a change in color treatment.

The Summation of Brightness.—A question has been raised as to the validity of the assumption that the visibility data, determined under one field condition for one spectral distribution of energy, can be applied to any other spectral distribution to obtain the corresponding luminosity data. It is also reasonable to ques-

tion the validity of the assumption that the brightnesses observed due to the energy intensity over any restricted spectral region can be compared with the brightness observed in any other spectral region. The visibility data is obtained by comparing, under fixed photometric field conditions and on the basis of equality, the brightness of a screen illuminated by a standard lamp with the brightness of a screen illuminated by the radiant energy comprised within a narrow region of the spectrum obtained from the same or some other source. Speaking from the viewpoint of the luminosity diagram the observed brightness due to the energy received on the screen from the standard is proportional to the mean value of its luminosity data. This is compared, not with a mean, but with an isolated value from some other luminosity diagram.

That this mathematical device may be consistent with visual experience, it is necessary to assume that the eye similarly averages brightnesses. In fact, the whole basis for the construction of visibility curves and luminosity diagrams may be expressed by saying that if the energy intensity at isolated wave lengths be simultaneously projected on a screen, the eye will evaluate the resultant objective brightness of the screen as equal to the sum of the brightnesses separately produced by the energy components; or, specifically, that if the separately evaluated energy intensities producing a "red" brightness, a "green" brightness and a "blue" brightness respectively be projected simultaneously on the same retinal area the resultant "white" brightness will equal the sum of the separate colored brightneses. This, it seems to me, is the necessary assumption at the basis of all visibility data and of the resulting method of computing luminosity from known spectral distributions of energy intensities. In brief, this assumption is that brightnesses of different colors may be added arithmetically. If this is not true, then the mean ordinate (or the area) of the luminosity curve has no meaning and no parallel in visual experience, and this would be also true of the visibility data considered as a whole. The test of this assumption should not present insuperable difficulties, for it is only necessary to show that the mean ordinate of luminosity curves, so determined from the visibility data, does bear a one to one relation to the observed brightness of the sources used in determining the different forms

of energy distribution, or to the observed brightness of the test screen illuminated by such sources. And in this, as in any other measurements assuming to be even reasonably accurate, the results should be associated with a description of the instruments employed and their accuracy. Here the eye is the indicating device. Therefore a determination of the sensitiveness of the eye within the range of intensities used, and for the field arrangement employed, is quite as essential to the results as the observations themselves. Has any one ever determined the probable sensitivity factor and scale of brightness for any particular photometric field ? Without such a determination is not the photometer an instrument of unknown accuracy ? Leaving out of consideration the eye as the indicating part of the instrument, is like thinking of the d'Arsonval galvanometer less moving parts and needle, as an instrument of precision. The photometer, like the magnetic circuit of the galvanometer is merely a means of establishing predetermined field conditions within which the moving element may function with known accuracy and on a fixed scale.

It seems to me there can be no question as to the great importance for illuminating engineering of what, for short, we may call the theorem of brightness summation. All the recorded work of H. E. Ives starts from this theorem, and I understand he has verbally stated it to be a necessary implication of the existing theory of visibility. Much of the work of Abney, Drysdale, Koenig, Exner and many others rests on an insecure foundation unless the truth of this theorem be granted or established. If its truth be established, then, as I shall now point out, the color analysis of illuminants lends itself to a peculiarly simple form.

Brightness and Color.—The psychology of vision leads to the conclusion that there are two separate and distinct visual sensations—brightness and color. The first, brightness, is quantitative in the sense that it is the intensity of the visual sensation. The second, color, is qualitative in the sense that it defines the quality of the sensation so far as the normal stimulus, intensity of luminous energy, is concerned. Black, as well as white, has been defined by psychologists as color. Certainly we see black, and the sensation aroused by a black image, as when we are in a completely dark room, is quite vivid. Yet the sensation of black-

ness is aroused by a lack of stimilus or a marked and sudden reduction in stimulus, and this should quite clearly differentiate it from all other colors which are intimately associated with the perception of a bright retinal image. The sensation of any degree of brightness must be of some color if it only be white. On the other hand the sensation of any color (other than black) must have some degree of brightness. To this degree at least, the sensations of brightness and color are intimately associated. They do not exist separately, and should not be considered as entirely sundered.

TABLE I.

	Color process factors			
λ (1)	R (2)	G (3)	B (4)	Visibility factors
0.700μ	0.002	0.000	.....	0.002
.690	.006	.001	.....	.007
.680	.016	.003	.....	.019
.670	.031	.005	.....	.036
.660	.049	.010	.....	.059
.650	.080	.019	.....	.099
.640	.130	.033	.....	.163
.630	.197	.058	.....	.255
.620	.266	.098	.....	.364
.610	.328	.160	0.000	.488
.600	.383	.236	.001	.620
.590	.426	.321	.002	.749
.580	.444	.415	.004	.863
.570	.436	.503	.007	.946
.560	.417	.565	.010	.992
.554	....	....	....	1.000
.550	.392	.588	.017	.997
.540	.359	.576	.026	.961
.530	.307	.526	.040	.873
.520	.212	.455	.065	.732
.510	.115	.325	.097	.537
.500	.063	.174	.109	.346
.490	.033	.073	.125	.231
.480	.016	.016	.123	.155
.470	.009	.007	.090	.106
.460	.006	.002	.061	.069
.450	.004	.000	.038	.042
.440	.002	....	.024	.026
.430	.001	....	.011	.012
.420	.001	....	.007	.008
.410	.000	....	.003	.003
.400	....	....	.002	.002

Therefore, if the trichromatic theory of vision is valid, and the theorem of brightness summation is proved, it seems to follow logically that the brightness of any stimulus confined to a single wave length will be the sum of the intensities of the three color

processes stimulated at that particular wave length. The brightness of any source will then correspond to the sum of the separate intensities to which the three color processes are stimulated over the spectral range of the energy intensity at the retinal image of the source. The hue of the source will depend on the relative domination of intensity in one or two of the three color processes. Finally, the ordinate of any point on the visibility curve for any particular value of retinal sensitivity should prove to be the sum of the ordinates of the corresponding points on three similar curves of chromatic visibility.

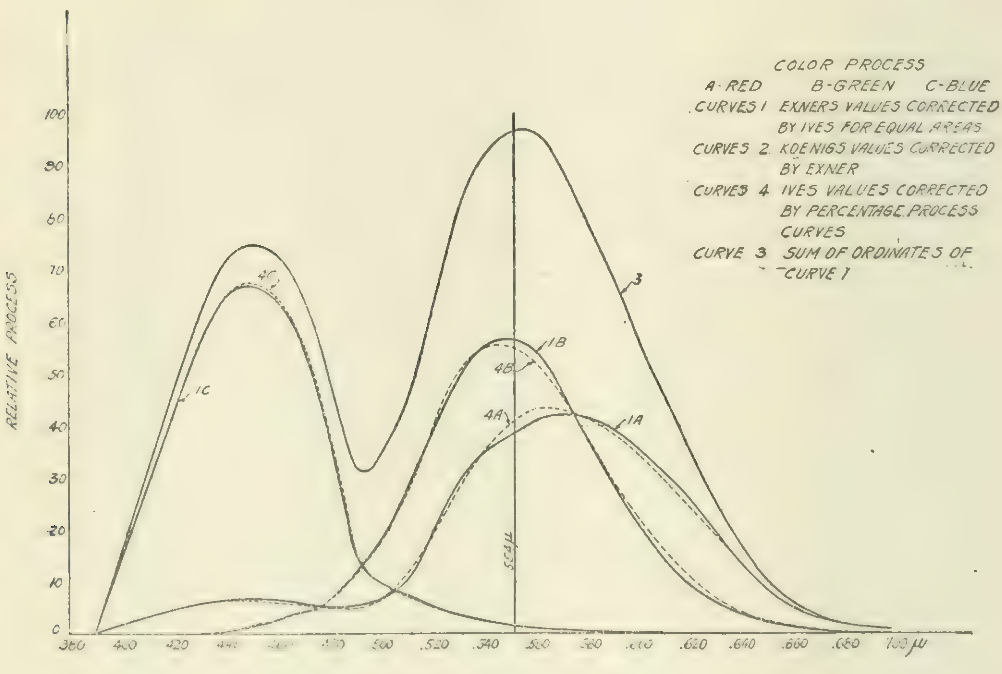


Fig. 3.—Color process curves.

If this be a fact, we shall thus obtain four sets of visibility factors, three of which correspond to the three color processes, red, green and blue, wave length by wave length, and the fourth is the sum of the other three at each wave length.

These four sets of visibility factors are given in Table I. They were prepared by the writer in 1915 as follows. The ordinates of Exner's color process curves as corrected by Ives for equal areas were added arithmetically to give the ordinates of a new curve, Fig. 3, which, if the above theory be true, and assuming that Exner's determinations were made under the same conditions used in determining the visibility curve, should be the visibility curve.

The visibility curve used was the mean of Ives' determination and that of Nutting's then available. The three color process curves were again drawn in per cent. of the total curve at each wave length. They showed certain marked irregularities which smoothed out as shown (Fig. 4). The resulting values in

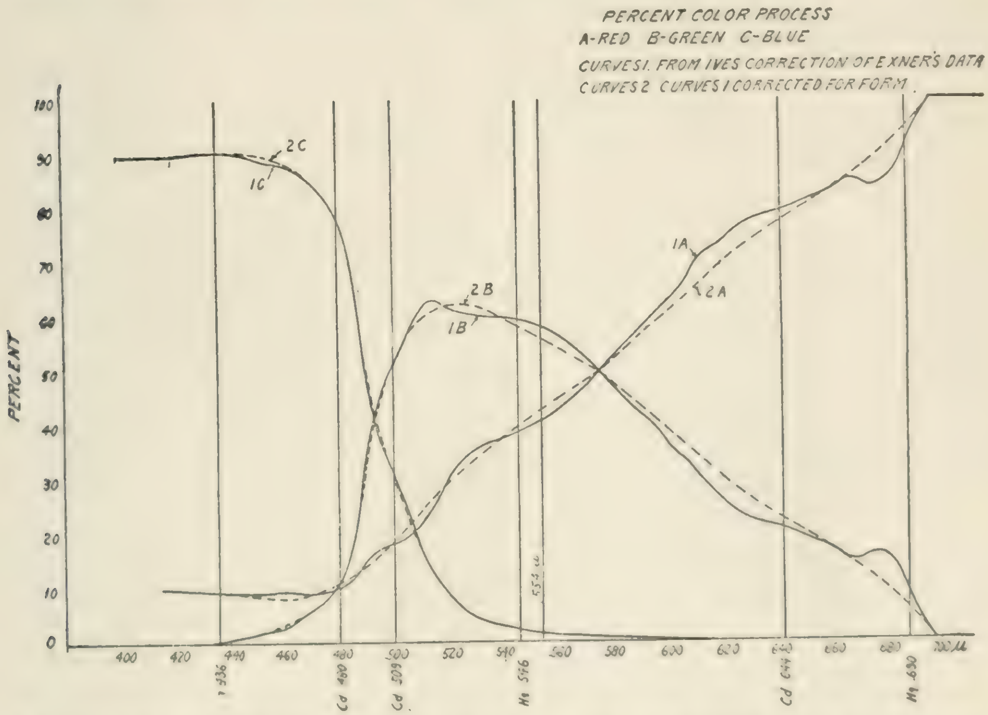


Fig. 4.—Color process curves drawn in per cent. of the total curve at each wave length.

$\frac{\text{per cent.}}{100}$ of the rectified curves were applied to the ordinates of the mean visibility curve to obtain the final curves shown in Fig. 1, and the data in Table I. These results give to the 'green' and 'red' processes by far the greater visibility values, indicating that within the region of cone vision, they do nearly all the work in arousing the sensation of brightness. This has been criticised as improbable. But such criticism is not in line with such knowledge as we have of the evolution of the color sense, nor with the facts discoverable by the study of colored after images.

These data were applied to several available spectral energy distribution curves having equal values at $\lambda = 0.545\mu$, to obtain the corresponding luminosity data. The mean value of each set of luminosity data from each energy distribution was then used to locate the color of the source in the Maxwellian system of tri-

angular co-ordinates (Fig. 5). The position of white was similarly determined from Abbott and Fowle's determination of energy distribution in the sun's spectrum. The position of each wave length in the spectrum was determined from the three sets of chromatic visibility data themselves using the three ordinates of the corresponding curves at each wave length as triangular co-ordinates.

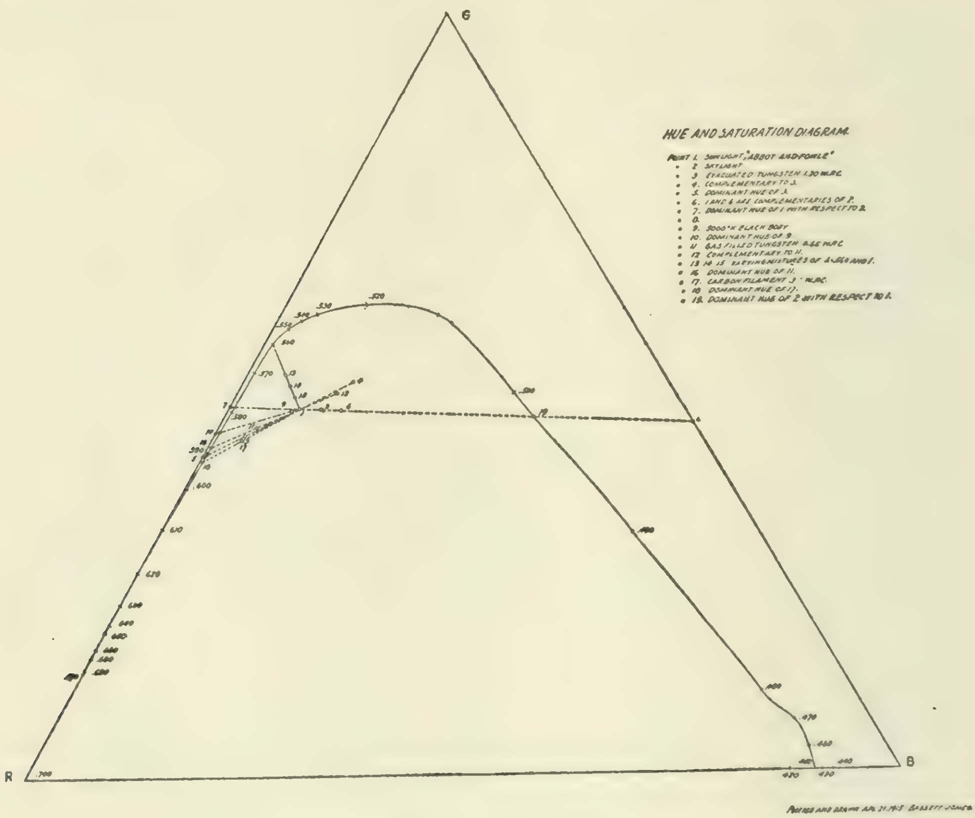


Fig. 5.—Hue and saturation in triangular co-ordinates.

A line drawn from "white" through the point in the triangular diagram representing any other "source" should intercept the spectrum curve at a point corresponding to the dominant hue of the "source" in question relative to the white adopted as standard. Furthermore the ratio of the distance from dominant hue to source and from dominant hue to white should give per cent. white or, inversely, it gives saturation. If the line be continued in the opposite direction through "white" to the spectrum curve and a point laid off in this direction from "white" a distance equal to the distance of the "source" from "white," the saturation and hue of the complimentary to the "source" is also determined.

A line drawn between the positions in the diagram of any two sources and continued both ways to meet the spectrum curve gives the hue and saturation of each source relative to the other.

The use of any position in the diagram as "white" has no effect on the position in the diagram of any other source. The only possible cause of such change in the diagram is a change in the fundamental visibility data, or in the color process data, and this is purely a matter of refinement in test method.

The only specific data necessary to determine the position of any source in the diagram is a measure of its spectral energy distribution.

Of course I realize that the above is largely speculative. However, the results, particularly as to dominant hue, do correspond quite closely to the determination of hue and saturation given by L. A. Jones in "The Color of Illuminants."[18] It is possible that the errors involved in conjoining data determined under such different conditions and for such different purposes may be quite serious. The "white" taken as standard may not be the same as that referred to by L. A. Jones as "white."

Furthermore, since the visibility data is established only for cone vision, the diagram is also presumed to apply only to pure cone vision. Check measurements of hue and saturation must be made with this fact in mind. I am not in a position, nor am I fitted, to make the determinations necessary to consistently check the idea that color and brightness must have some such intimate relation as that outlined for one value of retinal sensitivity. At all events I have never seen any discussion of the subject that, to my mind, made the contrary seem either logical or necessary. I wish to point out, however, that if the theorem of brightness summation is true then a hue and saturation diagram such as discussed above, is probably correct, and again, that if measurements of hue and saturation plot in such a diagram, the theorem of brightness summation is probably true.

A Postulate for Illuminating Engineering.—The second ratio conversion to be defined, namely that between intensity of brightness sensation and objective brightness, cannot be determined by measurement, for, as William James has said,[19] a sensation is a

[18] Trans. I. E. S., Vol. IX, No. 8.

[19] "Psychology," Chapter on Visual Sensations.

pure magnitude—"A unique fact of consciousness." It is not related quantitatively to any other preceding, simultaneous, or successive fact of consciousness by any common scale of measurement.[20] The only possible quantitative relationship between sensations of the same class is via the relative quantitative relationship of their stimuli. Brightness sensations, as such unique indivisible magnitudes,[21] are directly comparable only on a basis of equality (as in the equality of brightness photometric method). It was for this reason that the scale was omitted from the instrument used in the electrical analogy above employed.

It seems that in this undefinable ratio we have a fact behind which we cannot go. It therefore seems to be postulatic in its nature and quite fundamental. Therefore, I propose to relate intensity of brightness sensation and objective brightness by saying that *the intensity of brightness sensation is the objective brightness of the source.* If I were quite satisfied that brightness and color were actually associated as suggested above, I should have said that the intensity of *visual* sensation is the objective brightness of the source. This does not mean that the intensity of brightness sensation is the same as, or equal to, objective brightness. It *is* the objective brightness. In other words, the source is as bright as we perceive it to be. Therefore its brightness may be different to different eyes, and, if such a difference could be distinguished, it would be perceived as a real difference in the source brightness. Now a difference between the observations of any two individuals can be measured only when both sets of observations are reduced to a common scale, or compared quantitatively with some third set of observations which both observers accept as a standard of reference.

In the case of brightness sensation the observation is the thing observed, that is, objective brightness resulting from the concious act of perceiving brightness sensation, refers directly to no outer or physical fact or thing that can be used as a common reference. Hence, unless it be indirectly through other forms of reaction to brightness sensation than those involved in attempts to measure "objective" brightness, there is no way of comparing the brightness of a source common to two or more observers.

[20] See J. T. Ladd, "Psychology, Descriptive and Explanatory," p. 132.

[21] The mathematical distinction between magnitude and quantity is thoroughly discussed in Bertrand Russell's "Principles of Mathematics."

In an admittedly "far fetched" way this statement may be illustrated by employing the analogy of the shunt and milli-voltmeter used above, and assuming two observers, each attempting to measure the current flowing in a single conductor in accordance with the following method. The men are in separate rooms and cannot observe each other's instruments. Each observer has two shunts and two scaleless milli-voltmeters. One shunt is connected into the circuit to be tested. The other shunt is connected into an adjustable standard source of current which they have callibrated in common against what they have agreed to call a standard shunt and instrument combination. The standard is taken as the mean of their joint observations when using their own instruments to measure known currents. For lack of data, each man assumes that his own particular shunts and instruments give results so close to the standard set that any difference may be neglected. In other words each observer assumes that the scale of his own instrument and the sensitiveness of his own shunts is the same as the standard shunt. Furthermore, each assumes that his own instruments have a constant sensitivity equal to that of the standard instrument. The pair of shunts and instruments used by each observer corresponds to the two halves, or whatever other subdivisions is made, of the photometric field as seen by the observer.

The method of test is that each observer shall separately adjust the standard until the needle deflections are judged to be the same in both his instruments. He then reads off the adjustment indication on the standard, which compared with the callibration chart, gives a number taken to be a measure of the current flowing in the circuit under test. If both observers, employing this extraordinarily inaccurate method, come within a reasonable amount of finding the same current number, they are not only lucky, but they agree to call it correct.

Now the pair of shunts used by each observer are of the same sensitivity, but the pair used by one observer differs in sensitivity from the pair used by the other observer. Therefore while each may obtain the same current number they do it by equalizing needle deflections that are not the same for both observers.

This analogy, I think, is not unfair to our ordinary photometric methods, except that if the more complicated photometric fields

are used, so that the judgment is not essentially one of brightness equality, we might consider both needles to have a common axis and be seen against a common background.

To complete the picture our observers should insist on relating the angular displacement of the rheostat arm in the standard circuit rheostat and the angular displacement of the needles in the instruments, by calling the needle deflection the "apparent" angular displacement of the rheostat arm and further assert that the angular displacement of the rheostat arm is the "objective" needle deflection. They would have quite as much evidence for any such statement as has the illuminating engineer for a similar statement regarding what he calls "apparent" brightness and that "objective" brightness which to him, is an independent physical property of the light source.

By this I do not mean to say that our photometric methods are essentially wrong or useless. Certainly their multiple sources of error are well known. My object is to point out that the two observers may obtain equal so-called brightness readings because actually they do not measure brightness at all, but intensity of stimulus which is intensity of energy flux incident on the retina. The actual objective brightness of the photometer field may be quite different to each of them. If each observer could compare the deflection of the other's instrument with his own he might observe this difference.

Thus, there is a vast difference in kind, order, and class between the phenomena giving rise to the stimulation of the sensitive organ, and that which, as a result of this stimulation is seen at the source; but what is seen at the source (objective brightness) is identical with the result of the stimulation in the measuring instrument (intensity of brightness sensation.) Their ratio, if identities may be said to have a ratio, is unity. Therefore our measuring instrument itself, apart from its shunt and leads, has constant sensitivity; or at least in the light of what has been said, its sensitivity may be assumed constant. If this assumption works it is probably sound.

So far as my own, to me, perfectly clear conception of the matter goes, this disposes of the second ratio, leaving us only the first ratio or that between intensity of stimulus and intensity of sensation, to be determined throughout the range of "visible"

stimuli both as to quantity and quality. This determination is the essential key to the whole problem of illumination, for if we are then able to decide on an average, maximum or even arbitrary numerical value of such a ratio measured under certain fixed conditions of stimulation, and if we can also determine even but relatively, the variations of this ratio with variations in the character, quantity and distribution of the stimulus we should be able to establish some suitable measure for the effect of any particular arrangement of stimulus on the desired result, namely, the useful objective brightness of the field. If this can be done we shall be able to determine what particular arrangement of stimulus will result in the maximum available objective brightness of the field, or, in other words, what arrangement of stimulus enables the eye to function at or near its maximum sensitivity.

The efficiency of any particular arrangement of stimulus or illuminating scheme is then determined as a function or eye efficiency and not in terms of some purely physical arrangement and distribution of visible radiant energy evaluated by its result on the eye under the very special conditions determined by the photometer.

The Rating of Illumination in Terms of Brightness.—From what has been said above, it seems to follow that the *first* consideration in the design of any lighting equipment, must be of matters relating to the work demanded of the eye and its corresponding functional limitations, primarily its sensitivity in terms of brightness under the conditions set by the work. In this way only can we set such limitations on the distribution of luminous energy in the field, that the eye can operate at high efficiency.

Any *attempt to rate illumination in terms* of luminous flux distribution, or in terms *of foot candles* means nothing unless we also know what sensitivity the eye will possess under the working conditions imposed upon it. An average illumination intensity of 2.0 foot candles, might, under one set of conditions, produce the same brightness reading (by the eye) as will be produced under other conditions by 4.0 foot candles.

The foot-candles measure *power* (watts) on the arbitrary brightness scale of the photometer assuming a fixed visibility function and a known sensitivity. But the foot candles tell us nothing as to the ability of the eye to see brightness unless at the

same time we know the appropriate visibility data of the eye under working conditions. This visibility is not merely a function of the foot-candle intensity level of the field of view, but also of both past and present distributions of this intensity.

By this I mean, that if proper attention is given to the factor of brightness distribution so that no more work is demanded of the eye than it is normally capable of doing and it works at the peak of its efficiency curve, then the eye will function at maximum economy and will require the least possible amount of luminous energy flux. The work required of the eye is to translate luminous energy flux into brightness sensation. If this work is done at high efficiency, then less energy flux is required to produce a desired sensation intensity than if the efficiency of the eye is lowered. It is the sensation intensity or brightness that we "see".

This aspect of the problem of illumination has not received the attention it deserves, which indeed is strange, for it turns out to be the most important, if not the fundamental factor in illuminating engineering. No quantitative comparison of two distributions of radiation intensities over the field of view can be of use, from a visual standpoint, until we know definitely the character of the relation between radiation density at the retina and intensity of brightness sensation for each distribution. Any attempt to compare or rate two illuminating arrangements on the basis of foot-candle intensities must assume at the outset that the result in producing brightness sensation at the eye, not of the photometrist, but of the man who is going to work under one or both of the two arrangements, and when he is doing that work, is in some way proportional to the quantitative relation between the foot-candles in the two cases. Furthermore we must know that the measure of foot-candles in the two cases gives comparative results. The visual conditions in the photometer are assumed constant and the errors are reduced by reading, not the resulting brightness sensation, but the appearance or disappearance, of a geometrical figure, a result that is reasonably independent of the condition of the retina. Any other method must introduce serious error. This measure does not prove that the amount of brightness sensation produced in either case when the fixed photometer field is removed and the illuminated field substituted, will have even a remote correspondence to the ratio

between the photometric values obtained. Nor does it prove that two observers who get reasonably similar photometic readings receive correspondingly similar brightness sensations from the photometer fields, for in each case both fields are seen through the same ocular filter.

The foot-candle readings in the two cases will have some sort of quantitative relation only if the retinal conditions in the two cases can be assumed equivalent so far as concerns the resulting effect of the field brightness on the transforming factor of the retina.

Therefore any effort to rate illuminating systems on the basis of foot candles measured by a photometer or equivalent device requires the assumption of an equivalance that we know does not exist. It is like rating the mechanical output of steam engines on the basis of thermal units in the steam consumed and leaving the performance out of consideration. It measures input but not output, on the erroneous assumption that all eyes function alike under any and all conditions, when, on the contrary, we know that such is by no means the case. The result of any attempt to accent the importance of foot candles at the expense of brightness distribution as a gauge of proper illumination, can only have a deterrent effect on the art, for it distracts attention from the fundamentals of illuminating technology to a purely arbitrary unit of measurement, and teaches us to forget that the problems of illuminating engineering are primarily ocular.

III. DEFINITIONS.

Kinds of Brightness.—Our present nomenclature defines two kinds of brightness—diffuse and specular. For purposes of analysis this distinction is convenient. Actually there is but one kind of brightness—the intensity of visual sensation.

This distinction is actually one of appearance. Any object that either generates, transmits or reflects luminous radiant energy, is said to exhibit diffuse brightness when it appears to be equally bright from every angle of view, and independent of the direction of the incident illumination. Brightness of this kind is a visual property of practically every optically homogeneous body showing uniform temperature radiation, such as incandescent metals. It is closely approached in the reflection of light from a few sub-

stances such as finely ground magnesium carbonate crystals lightly pressed into cake form by a plane glass plate or, in a light ether-gum vehicle applied by infiltration to a finely woven cotton fabric; the white smoke of magnesium, burned to oxid, deposited on a smooth surface; carefully pumiced white celluloid; carefully depolished homogeneous dense white opal glass, in which the opalizing is accomplished under carefully controlled temperature conditions.

The last mentioned is about the only servicable substance that shows a close approximation to perfectly diffuse brightness by transmission.

All substances, even carefully made mirrors (excepting perhaps mirrors prepared by methods of scientific precision) exhibit more or less diffuse brightness. So many substances of practical every day import exhibit a fair approximation to diffuse brightness either by reflection or transmission or both, that it is impossible to enumerate more than a few of them; such as, white plaster, blotting paper, "dead" finished paints, uncallendered papers, woven fabrics, opal glasses, finely and deeply roughened and heavily etched glasses, unpolished fine crystalline stone surfaces.

Specular brightness is due to a restricted retinal image or a spot of marked brightness in a retinal image whose brightness is generally so low that the contrast is noticeable.

As a term, Specular Brightness evolved from the term specular or image reflection such as occurs in a mirror. But a mirror exposed to a source showing only diffuse brightness like the sky, shows only what has been called diffuse reflection and therefore, only diffuse brightness. So the distinction is relative only. The mirror exhibits specular brightness only when the area intercepted at the mirror by the solid angle subtended at the retina by the source (Fig. 6), falls within the periphery of the mirror, so that there exists a penumbra of lower brightness surrounding the image of the source as seen in the mirror. While in Fig. 7, where the entire surface of the mirror is filled by the image of the source, there will be no appearance of specular brightness in the mirror, although if the visible surroundings of the mirror are less bright than the source, the image of the mirror on the retina will be a spot of marked brightness in a darker field and the net

effect on the eye will be the same as a case of so-called specular brightness.

As has been pointed out, a mirror may or may not exhibit specular brightness. The term "specular reflection" is misleading. A better term would be regular or image reflection, confining the use of the word "specular" to the appearance or brightness of any surface showing marked brightness contrasts, and whether or not the reflecting surface acts as a mirror.

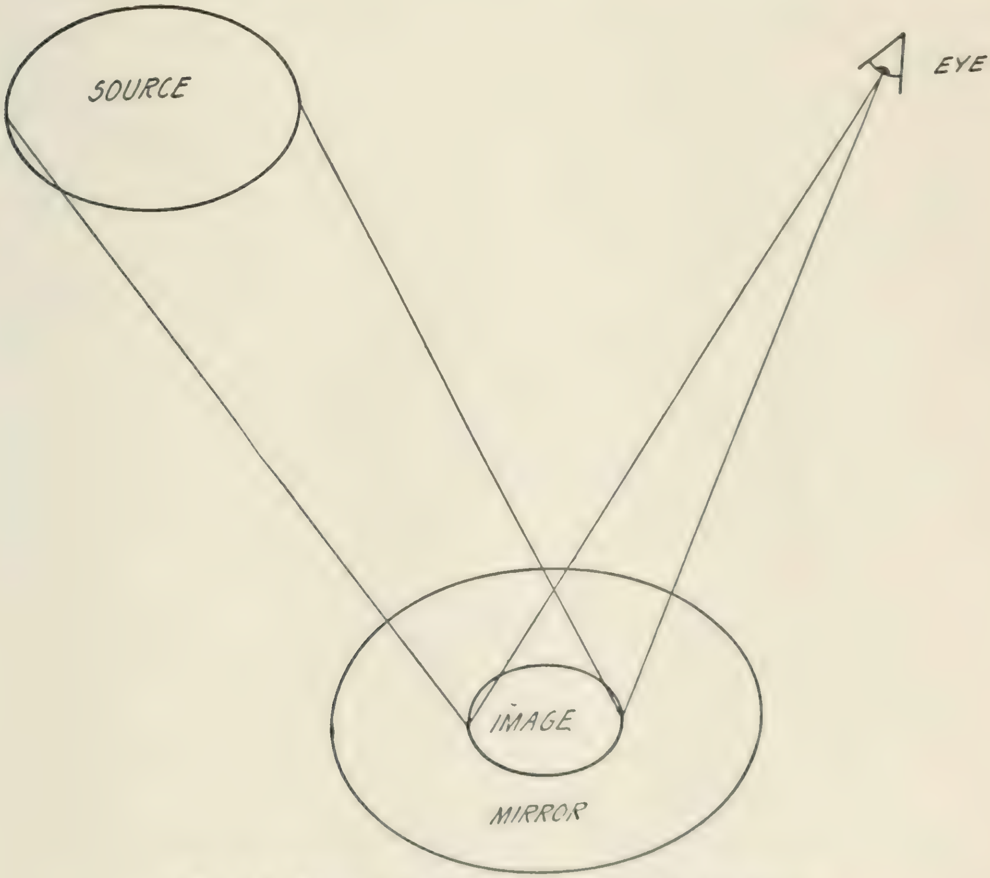


Fig. 6.—Reflection when the mirror exceeds the image.

Thus we should draw a distinction between "scattering" as applied to reflection or transmission, and "diffuse" as applied to brightness. And, again, between "direct" or image reflection and "specular" brightness.

Now the "seeing" of objects is accomplished principally by the diffuse brightness they exhibit. Specular brightness usually reduces visual acuity and is therefore to be avoided where not essential to bring out "high lights". It therefore becomes a

matter of vital importance for us to study the reflecting qualities of the materials we are required to illuminate so that we can determine what sort of brightness they will exhibit when lighted by sources of various kinds and dimensions, and that may exhibit themselves both specular and diffuse brightness in different relative degrees. This, in itself, is a large subject and one that is by no means settled as to method or results.

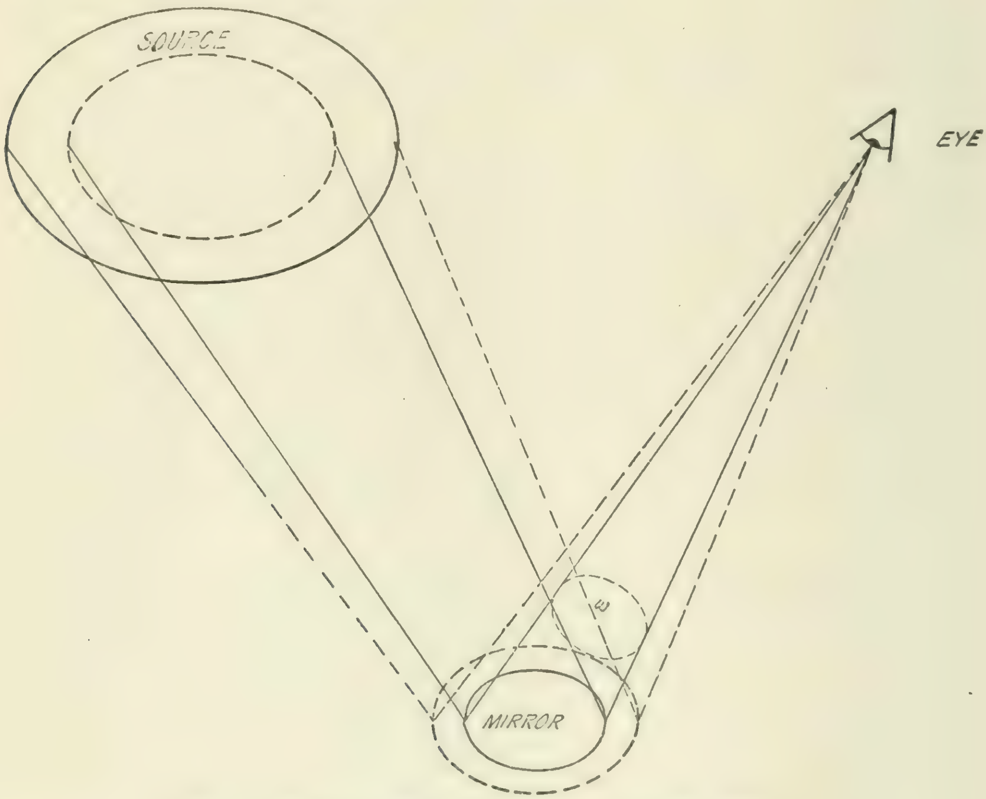


Fig. 7.—Reflection when the image exceeds the mirror.

The Unit of Brightness.—Since brightness is fundamental in the art, it is obvious that our primary unit must be a unit of brightness sensation. Brightness sensation may be quantitatively defined as the product of the intensity of sensation over the retinal image of the source and the area of the image. This quantity is related to the product of the intensity of the luminous energy incident on the image and the image area, and hence to the rate at which the energy is received on the image. This relation, as has been pointed out above, is by no means a simple proportion, and depends on the many factors controlling visibility and retinal sensitivity.

Again, speaking from the viewpoint of the appropriate luminosity diagram, which is determined by the spectral distribution of the energy intensity, the conditions under which it is received, and retinal sensitivity, we may say that the brightness sensation received is the product of the sensation intensity represented as the mean ordinate of the luminosity diagram, and the area of the retinal image.

Obviously a retinal image is essential if any sensation is received, and therefore the source must have some area. Any elementary source, therefore, must be a surface source, and treated as such if we are to develop any method of dealing mathematically with brightness relations that will give results consistent with the corresponding experimental facts.[22] Our present mode of dealing with these matters assumes a radiating mathematical point as a starting point to which the inverse square law applies throughout space. This is not the way a surface radiates and consequently it can hardly be expected that the implications of such an assumption will lead to exact or consistent results,—as indeed they do not. This is evident from a reading of the existing mathematical treatment of the subject—results are always given as only approximately correct within relative dimensional limits that make the deductions inapplicable to most practical problems.

It is perfectly evident that a point source, having no dimensions, can have no retinal image. Therefore it can have no brightness, and, as a direct corollary of this, it can emit no light. It seems then, quite illogical to adopt a postulate as the basis of a system of measurement that can be proved so easily to be inconsistent with the very elements of experience it is designed to explain.

Furthermore, a luminous spherical shell which is the only possible approximation in experience to the purely mathematical radiating point, has actual brightness relations which do not correspond with the brightness relations implied by the mathematical assumptions inherent in a radiating point. A radiating point implies radiation according to the inverse square law. We are then justified in employing the point source as a basis for further

[22] This matter will be treated in the writer's forthcoming paper "Brightness—II; The Controlling Factor in Illumination."

analysis only if we find by experience that radiation does follow the inverse square law. We find that it does so only within approximately infinitesimal dimensions as to size of source, and most, if not all, actual sources are far from being infinitesimal in surface area. I therefore suggest that the mathematical relations of finite surface radiators give results quite in accord with experience and therefore should be adopted as the basis of our system of measurement.

So we must start with a source of some size and shape the radiation characters of which are as nearly as possible in accord with our actual experience of luminous objects. For reasons that must be perfectly obvious, this elementary source shall emit radiation in accordance with Lamberts' Law. Therefore it exhibits diffuse brightness. It may then conveniently be a flat surface of unit area, and when viewed normally its brightness relations will be the simplest if it be circular in shape.

If we please, we may then define the unit of brightness sensation as the sensation produced by this source viewed normally under certain fixed conditions as to distance from the pupil, size of pupil, surroundings, etc.—in fact when all factors effecting retinal sensitivity are fixed—also, when the spectral distribution of energy intensity at the retina and its visibility data are known. This, then, becomes our Unit Light Source. The Unit of Objective Brightness is the intensity of brightness sensation produced by it under the set conditions of observation. This method of defining our units from the sensory viewpoint throws the variables where they belong, into the light source and the conditions under which it is observed, and not, as at present into the sensation, where they do not belong.

Next, we may evaluate the luminous value of the radiant energy at any point in space by observing the objective brightness of an ideal reflecting or transmitting screen such as the photometer test object, placed at the point in question and comparing its brightness on a basis of equality with a screen whose objective brightness is determined by comparison with the brightness of the unit source. This is, of course, the ordinary method of photometry, but as mentioned above, we must not consider that the objective brightness of the screen so determined and observed will be the

same as its objective brightness when observed under conditions other than those obtaining in the photometer.

The objective brightness of the screen thus determined, is measured against a scale of brightness based on the objective brightness of a similar screen when illuminated by the unit source at unit distance, and when the area of this screen is small in comparison with its distance from the source. Otherwise its brightness will not be uniform. Also the scale determination must be made under the same conditions of observation that apply in the photometer, or the result may not be comparable.

Then, if we call our unit light source the *Candle,* we may also call the objective brightness thus observed on the screen at unit distance from the unit source, the *Foot-Candle,* which is thus in reality a secondary unit of objective brightness.

In this method employing brightness as the fundamental and only factor in lighting, the candle is the only unit necessary. We may still employ the lumen, but it is to be conceived as radiant energy rated in terms of its potential production of objective brightness or sensation intensity on the ideal screen. Any statement of lumens as a measure of luminous flux must be associated with some fixed scale of brightness, and holds only within the limits of visibility and retinal sensitivity which determine the brightness scale of response.

The relation between brightness and luminous flux is established as follows. Brightness being an intensity must be mathematically related to an intensity of luminous flux. The intensity of the flux is conveniently measured by the *rate* at which it is received on or emitted by unit area of the ideal screen. This intensity converted into brightness is measured in candles per unit area, or the equivalent of this brightness in terms of the brightness of the unit light source.

Our present nomenclature defines brightness in terms of candles per square inch or its equivalent, and flux in terms of lumens per square foot or some other area in the same scale as the brightness measure. Thus, in reality, both measure the same thing in different units. So the brightness is a measure of the luminous value of the radiant energy. In other words, brightness is a measure of lumens. All photometric methods stand as evidence for this fact.

The lumen merely provides an intermediate mathematical link between the brightness of the source and the brightness of the illuminated object or screen. I say the lumen is a mathematical link because it is purely ideal and has no existence either as visual sensation or as a physical fact. There is, in fact, no actual direct physical linkage between the brightness of one object and another. The linkage exists between the specific intensity and character of the radiant energy emitted by one object and received on and emitted by another object. The eye merely scales the results in terms of visibility controlled by retinal sensitivity. The laws of emission, transmission, reflection, and diffusion are the laws of physical optics. The laws of brightness are, as explained above, the laws of retinal behavior.

If we can provide a direct relation between the brightness of the source and the brightness of the illuminated object, all our calculations will contain but one factor—*brightness*.

In thus re-establishing our units on the basis of sensation intensity it must be realized that they are statements of purely arbitrary values of fundamental variables that may be treated as constants only with this understanding of their limits in mind. The scale of measurement set up must not be interpreted as applying within a system of visual co-ordinates other than that determined by one value of visibility and one value of retinal sensitivity. Within such limits of sensibility the units and the scale, only as a matter of convenience, may be treated as independent of the observer. Again, within such limits, and only as a matter of measurement, not of useful visual function, the objective brightness of luminous objects can be treated as if it were independent of the sensibility of the observer's eye. The *as if* is important.

DISCUSSION.

A. S. McAllister (Written Discussion): By bringing into juxtaposition the three condensed, but widely-separated, parts of the author's paper to which he has called particular attention as containing his unanswerable arguments, namely, the items on pp. 725 and 750, one discovers an almost ready-made answer thereto. He puts the question, "Is the wall of this room bright if no one is here to see it?" and replies thereto that the intensity of brightness sensation *is* the objective brightness of the source, and

finds some kind of an analogy with the sensation which he calls "feeling of warmth."

Ages ago, before the possibility of developing temperature-measuring instruments was realized, the intellectuals proved to their satisfaction that their own method of estimating the temperature in an enclosure involved a resort to the "feeling of warmth." One can readily believe that they came to the conclution that whenever they removed themselves from their cave abodes, and left their log fires burning therein, the enclosure ceased to have any temperature because no one was there to experience a "feeling of warmth"—the temperature itself being to them identical with the sensation created thereby.

However, civilization advanced, and temperature-measuring instruments more accurate than the human body were developed, so that one may now ascertain the exact temperature of an enclosure without subjecting his body to the "feeling of warmth."

In his present paper the author has rendered a real service in emphasizing the difficulties and limitations encountered in evaluating brightness in terms of the "sensation of brightness." Unfortunately, however, like the intellectuals of old, he has come to the conclusion that when the eye (the only brightness-measuring instrument known to him) is not present there is no brightness!—the brightness itself being to him identical with brightness sensation.

It is hoped that, in connection with his forthcoming paper on "Brightness as the Controlling Factor in Illumination," his pessimism will turn to optimism and he will bring forward some constructive suggestions which will lead to the development of instruments for measuring brightness devoid of the defects found in the human eye. Just what our good old friend selenium, or some of its undisclosed cousins, may have to offer in this connection we do not know; but the possibility of utilizing it in combination with a constant, or a definitely adjustable, solid angular exposure —so as to eliminate the distance calculations—should go far towards convincing the author that brightness itself and brightness sensation are by no means identical.

Morgan Brooks: Mr. Jones has said that the point source of light is an absurdity. If this is true, I wonder how we ever see a

fixed star. According to the astronomers, a fixed star is a fixed point of light. It has occurred to me, in connection with the paper, that if we had no irradiation of the atmosphere, maybe we couldn't see a fixed star. It wouldn't occupy any space at all on the retina. Maybe it is an imperfection of the eye. I want to know why it is absurd to make use of a conception of a point source, when we have such a good natural illustration of it in the stars.

A. H. TAYLOR: There is a general misconception in regard to Lambert's Law, a comment which may or may not be pertinent to the paper under discussion. An article by Trotter has recently been published in the British journal, *The Illuminating Engineer,* which shows that Lambert's "Cosine Law" does not refer to reflected light, but to incidental light, that the flux density is identical to the cosine in the angle of normal light. When we speak of deviation from Lambert's cosine law, we simply mean that we don't know what the law really is. According to Trotter, Lambert never stated that light is reflected according to any such law as that.

LEONARD T. TROLAND (Communicated): I have read Mr. Jones' suggestive paper with great interest, since it touches theoretical problems concerning which I am constantly thinking, and inculcates principles which I have myself urged upon the attention of illuminating engineers. Illuminating practice necessarily concentrates itself upon the production of forms of consciousness, and the psychological conceptions of color and brightness are embedded in all of its most essential theory. The illuminating engineer should, therefore, easily learn to look upon psychological data and principles as concrete realities.

I am grieved that Mr. Jones should regard me as a naive realist; if a realist at all, I certainly would claim to be a very sophisticated one, and although I scarcely agree with Bradley I am quite in sympathy with Bishop Berkeley. As a philosopher, however, I can readily pardon Mr. Jones for not seeing that in my paper on "Apparent Brightness" I actually mean to promulgate the same views which he himself advocates. I employ the term "apparent brightness" as a two-word synonym of luminosity,

which is the brightness aspect or dimension of visual consciousness. It is perfectly evident, however, that this "apparent brightness" this visual consciousness, is out in visual space in front of the individual observer, and not in his brain. This is because he *sees* it there. It is a property of *external* objects because all objects of perception are external; not external to consciousness, of course, but to the body of the observer. An external object, however, is not necessarily a *physical* object. As I understand physics, all of its concepts reduce to terms of the gram, the centimeter, the second and units of dielectric capacity and magnetic permeability. Luminosity simply refuses to be split up into any such components, or indeed into any components at all. On all of these points, I believe, Mr. Jones and I are actually in essential agreement.

The distinction between "apparent brightness" and mere "brightness" which I seem to imply in my paper is simply that between luminosity—a property of the individual visual consciousness—and the quantity which we measure in lamberts or in candles per square centimeter. I do not believe, however, that I imply either the metaphysical or the physical reality of this quantity; quite the contrary, in a section of my paper later than the one to which Mr. Jones has devoted the most attention I opine that the lumen—and hence all of its derivatives—involves a dimention (for the psychical), which is absent from the "c. g. s." or physical scheme entirely. I go on to say: "Equal quantities of *light* are quantities of radiation such that they generate in the average, normal, visual system equal degrees of apparent brightness. The ultimate criterion is the judgment upon consciousness, even for the physical photometer." Here I clearly agree absolutely with the opinions expressed by Mr. Jones. Photometric concepts are curious hybrids, the offspring of a *marriage de convenance* between physical and psychological ideas. Photometric brightness almost certainly has no reality beyond the figures which represent it, but this does not prevent these figures from being of the utmost value to us, because—as Mr. Jones acknowledges—they combine the various alien factors involved in the visual process in such a way that we can predict the result in the "average, normal," individual's consciousness. Light is simply physical radiation multiplied by a factor which depends upon the

human psycho-physiological organism and there certainly can no longer be any excuse for carrying out the multiplication.

It seems to me that Mr. Jones' distinction between "brightness sensation" and "objective brightness" is quite futile. This he eventually acknowledges when he states that one of them is the measure or degree of the other. A psychologist naturally balks at the idea of an "objective brightness resulting from the conscious act of perceiving brightness sensation." Nowadays those psychologists who still adhere to the study of consciousness regard the latter simply as the sum of its own contents and on purely introspective grounds make no distinction between sensation, perception of sensation, conscious act of perceiving and that which is sensed. As I endeavored to suggest in my paper, already referred to, these are merely so many clumsy ways of saying the same thing. Luminosity is a fact of consciousness, but the sensation of luminosity, the perception of the sensation of luminosity, and the apperception of the perception of the sensation of luminosity have thus far escaped our observation. The term "sensation" is most properly used, I conceive, to stand for the determinative linkage or relation of dependency, between factors of consciousness—such as luminosity—on the one hand and the purely physiological processes of sense-organs on the other. I should not be surprised if this were actually what Mr. Jones has in mind.

BASSETT JONES: The question of temperature and feeling of warmth it seems to me is covered in my paper. To make what I mean clearer, note that a room at a given temperature which might feel comfortable to a man from New York would seem insufferably hot to an Esquimo from Greenland and cool to a South Sea islander. An old man or a man with a fever would feel chilly in an atmosphere that would be torrid to a fisherman from the Banks or to a robust, healthy individual. One man breaks the ice for his morning bath—another must use tepid water. The question is not one of temperature but of the intensity of sensation produced.

As to the question of the stars, raised by Prof. Brooks, it is to be noted that at their immense distances the stars are practically point sources. But in modern illumination the sources—fixtures, ceiling, walls—by no means approach to point sources. Indeed

the error in considering them to be point sources is commonly very great—100 per cent. or more. From the viewpoint of illumination, the stars are luminous discs of very small radius—so small as to be below the resolving power of the eye, and the consequent spread of the retinal image makes them seem much larger than they should appear to be on any basis of pure geometrical optics. What we "see" is the enlarged retinal image of the star, not the infinitesimally small geometrical mirage. As Prof. Brooks suggests we see the stars only through an imperfection of the retina.

Concerning Lambert's Law, let me say that I read the article by Trotter to which Mr. Taylor refers, and, perhaps, I misunderstood Trotter. In any case, the point does not effect my main argument.

I am very glad indeed to thank Dr. Troland for his understanding discussion. Some one has said that most arguments start over the lack of a common definition. Mr. Troland makes clear to me that we both stand on the same ground. Our postulates are identical. Any disagreement is then a difference of logic and not of fact.

I had thought my paper clear on the point that the bright object is "out in front of the individual observer," and "because he sees it there" as a response to the stimulus. What he sees therefore depends on the stimulus and upon its effect on the beholder. So it is not physical, for "physical" qualities do not depend on any quality of the beholder for their being. Brightness is one such non-physical quality.

Yet, if Worlitz Schlick's "Space and Time" is a true presentation of modern physical theory, then it seems that even physicists begin to doubt the independent character of what we call physical things. "The objects of physics, the space of physics * * * is a product of our conceptions" (p. 78). The substance of this statement is, of course, much older than Schlick, Einstein, or Planck. In fact Schlick's entire argument is almost Aristotelian in its antiquity.

No one desires to deny the value of physical conceptions. I wish to point out that luminosity—and its derivative, brightness—not being subject to resolution into any fixed components, should not be so treated except with the distinct understanding that the

results are true only in one fixed set of visual coordinates such as those established by the photometer for light of fixed color, and that they are not true in any other set of coordinates. We must not treat luminosity and brightness as universally subject to a set of laws that hold only under one set of conditions.

Perhaps it is well only to use the word "brightness" as meaning the luminosity observed under one set of conditions. In such case brightness may be treated *as if it were* a physical quantity. But the conditions in illumination are not fixed. In fact they are quite variable, and usually all vary widely from the standard conditions set by the photometer.

In closing, let me apologize to Dr. Troland for calling him a realist.

THE EFFECT OF VARIATIONS IN INTENSITY OF ILLUMINATION ON FUNCTIONS OF IMPORTANCE TO THE WORKING EYE.*

BY C. E. FERREE AND GERTRUDE RAND.

SYNOPSIS.

Intensity is only one of the lighting factors which influence the functional powers of the eye. In a former study it was shown that one effect of increase of intensity may be obtained for a good installation and another, quite different, for an installation where the increase of intensity is accompanied by an increase in the number or the brilliancy of the bright surfaces in the field of view. The present study has been conducted only under conditions in which the increase of intensity did not result in the introduction of harmful glares into the field of view. Also much wider ranges of intensity were employed, and the effect on other functions of importance to the working eye have been tested:—acuity, power to sustain acuity, speed of discrimination, and speed of adjusting the eye for clear seeing at different distances. The effect of increase of intensity has been measured both on normal eyes and on eyes with small errors in refraction of a type and amount which are of very frequent occurrence, even in the corrected eye.

Intensity is only one of the lighting factors which influence the functional powers of the eye. In a former paper[1] we have shown that one effect may be gotten for increase of intensity for a good installation and another, quite different, for an installation where the increase of intensity is accompanied by an increase in the number or brilliancy of the bright surfaces in the field of view. In the case of the present study, we have worked only under conditions in which the increase of intensity did not result in the introduction of harmful glares into the field of view. We have also used much wider ranges of intensity and have tested the effect on other functions of importance to the working eye.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] Further Experiments on the Efficiency of the Eye Under Different Conditions of Lighting. TRANS. I. E. S., 1915, X, pp. 448-502.

Some of the beneficial effects of increase of intensity may be summarized in the following statements.

(1) There is a slow but substantial gain in *acuity,* for all but low intensities where the gain is rapid. This gain moreover is greater in case of small uncorrected errors in refraction than for the normal eye. Such errors in refraction are very common. Even the corrected eye, more particularly in cases of astigmatism, is rarely corrected with such precision as not to be considerably benefitted by an increase in the intensity of the illumination under which it works. The principle underlying the benefit of increase of illumination is not hard to understand. With reference to the object seen, or the work, clear seeing is affected by two conditions—an increase in its size or the visual angle subtended, and an increase in the amount of light which it receives. An increase in either is of benefit, more particularly when acuity is subnormal through an uncorrected astigmatism or some other defect. In case of all of the functions which we have tested: acuity, power to sustain acuity, speed of discrimination, and speed of adjustment for clear seeing at different distances, the subnormal eye approaches more nearly to the normal eye in functional power as the intensity of the illumination is increased. There is a strong probability also that the middle aged and old eye benefit more by an increase of illumination than the young eye.

The fact that the acuity of the eye with a small defect in refraction approximates more nearly to that of the normal eye with increase of illumination should be of interest to the ophthalmologist as well as to the lighting specialist, inasmuch as it indicates that small errors in refraction or in their correction cannot be picked up so readily at high as at low illuminations by the acuity test. Apparently the effect of small differences in the resolving power of the refracting media on clearness of seeing tends to be obscured or obliterated at high illuminations by the greater power of the retina to discriminate the slightly blurred detail at these illuminations.

(2) There is a gain in the *speed of discrimination.* This gain is very great from low to high illuminations when the object is small. The phenomenon is still present to a very marked degree with a visual angle roughly approximating the details in 10-point

type at the conventional reading distance, 33 cm. (13 in.). Just what relation the gain sustains to size of object or visual angle will be determined in a later investigation. The gain is much greater for the eye with a small uncorrected error in refraction than for the normal eye.

(3) There is a gain in the *speed of adjustment* for clear seeing at different distances. The adjustment for seeing at different distances involves changes both in convergence and accommodation. Clearness of seeing is both the incentive for these changes and the check on their accurate accomplishment. It is only natural to suppose therefore that whatever leads to quick and accurate seeing favors quick and accurate changes in adjustment. With increase of the intensity of light the eye with defective refraction gains in its speed of making these adjustments more than the normal eye.

(4) There is a gain in the *power to sustain clear seeing* when the size of the test-object or the visual angle is kept the same for the different illuminations. Since we cannot at will change the size of the work or the object seen, this is obviously the more significant test condition. This gain is very great when a comparatively small visual angle is used. Obviously a large visual angle could not be used to measure this function because the acuity or power to see clearly might suffer great loss without blurring the vision of a large angle. Again there is a very marked benefit for the defective eye in increasing the intensity of illumination.

(5) If the task, not the visual angle, is kept the same for the different illuminations, *i. e.*, if the working visual angle is changed to sustain the same percentage to the minimum visual angle at which the observer can just discriminate detail at the different illuminations, there seems to be no measurable effect of increase of illumination on the power of the normal eye to sustain the clear seeing of its object for a period of time. Working with these same visual angles at the different illuminations the normal eye, however, made slightly astigmatic by a weak cylinder gains a great deal in its power to sustain the clear seeing of its object with increase of illumination.

All of the functions referred to above are aspects of acuity. They are aspects, however, which are not brought out by the conventional method of testing acuity. The conventional test of acuity takes little account of either speed or power to sustain, two aspects which are not only of great importance to the working efficiency of the eye but are extremely sensitive indicators of differences in functional power. Add either of these aspects to the method of testing acuity and the effect is very similar, so far as sensitivity is concerned, to that obtained when an amplifier is added to a physical recording instrument.[2] For example, changes of intensity which produce comparatively small differences in acuity as ordinarily tested, cause very large changes in the speed of discrimination and the power to sustain acuity. The conventional acuity test is, comparatively speaking, not only insensitive but it is not sufficiently comprehensive in the range of aspects covered to bring out differentially some of the most important functional powers of the eye.[3]

(6) A sixth point of importance is whether the eye tends to fatigue more under the high illuminations. Using the method for testing fatigue employed in all of our former work, no significant difference in effect could be found for reading for three hours from uniform type and paper under well diffused daylight illumination with 0.4, 2, 4, 6, 8, 12 and 36 foot-candles of light on the reading page when the eye was adapted for fifty minutes to each intensity of illumination prior to beginning the test. The

[2] The analogy to an amplifier is perhaps misleading. The greater result is obtained by testing the aspects of clear seeing which are the most strongly affected by any condition which augments or depresses functional power, not by a process of amplifying or magnifying the real effect.

[3] Further, a consideration of the number of factors on which acuity depends: intensity of illumination; time of exposure of test-object (the effect of time of exposure is enormous at low illuminations); state of adaptation or sensitivity of the retina; number of meridians in which the resolving power is tested simultaneously, or successively if a test-object taxing the resolving power in only one meridian is used (if such a test-object is employed the determination should be made certainly in no less than four meridians); brightness of preexposure; brightness of surrounding field and evenness of brightness of surrounding field; breadth of pupil, etc., leads one to a realization of how little a statement of acuity means unless the exact conditions under which the determination is made are given.

When a simple test-object is used there is in general a tendency to overestimate acuity. The power to see more complex objects is not fairly gauged by a test-object which taxes the resolving power in only one meridian even when successive tests are made in different meridians, *i. e.*, the effect of the slight distortions present in the refracting action of nearly every eye, which tends to confuse the discrimination of complex objects, is lost on the simple test-object.

light was received from a skylight covering the entire ceiling, beneath which were swung large diffusion sashes of ground glass filling the entire opening. The control of intensity was secured by an elaborate system of curtains, thin white and light-proof, also covering the entire ceiling. There was also no significant difference at these illuminations in the tendency to produce discomfort, as measured by the method employed for this purpose in our former work, under the conditions of adaptation and with the distribution and control of illumination described above.

THE EFFECT OF INTENSITY OF LIGHT ON ACUITY.

In one series of experiments four observers were used and the acuity was determined at 0.001, 0.005, 0.01, 0.015, 0.02, 0.05, 0.1, 0.2, 0.4, 1, 2, 3, 5, 10 and 20 foot-candles of light normal to the test-object. The eye was adapted to each illumination by a thirty-minute practice series with proper rest periods. The broken circle (the international test-object) mounted on a rotating graduated dial, was used as test-object. In making the observation all that was required of the observer was to indicate the direction in which the opening pointed. The judgment on which the estimate of acuity was based was thus reduced to very simple terms and an objective check was had on its correctness. In the final series of determinations this opening was turned in haphazard order right, left, up, down and the four 45-degree positions; and a correct judgment was required in five out of the eight positions. The breadth of the opening was measured on a micrometer comparator and the visual angle computed. The coefficient of reflection of the test surface was 78 per cent. The pre-exposure and surrounding field were made in each case as nearly as possible of the same brightness as the test surface. An exposure of 1 second was allowed for each judgment. The work was done under artificial illumination, the light of frosted type B mazda lamps. The angle of incidence of the light on the test surface was kept constant throughout the experiments. Constancy of position of the observer's eye was secured by biting a mouthboard in which the impression of his teeth had been previously been made and hardened in wax.

From 0.001 to 0.1 foot-candle the minimum visual angle changed from 7.143 to 1.213 minutes of arc, a gain of 488.9 per cent. in acuity; from 0.1 to 1 foot-candle it changed from 1.213

to 0.741 minutes of arc, a gain of 63.7 per cent. in acuity; from 1 to 5 foot-candles it changed from 0.741 to 0.516 minute of arc, a gain of 43.6 per cent. in acuity; and from 5 to 20 foot-candles it changed from 0.516 to 0.477 minute of arc, a gain of 8.2 per cent. in acuity. A curve showing the average results for the four observers is given in Fig. 1.

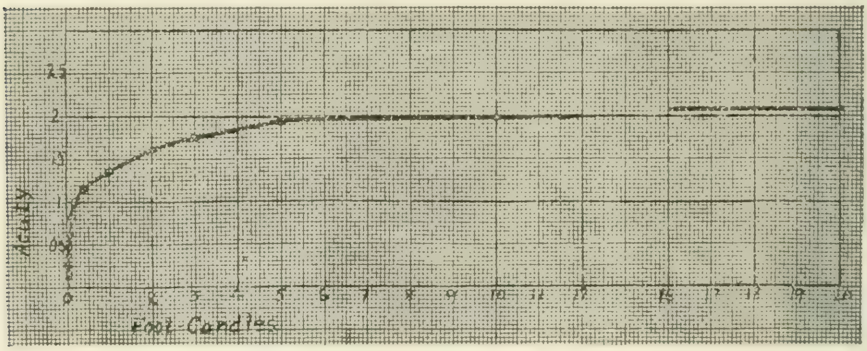


Fig. 1.—Showing the effect of increase of intensity of light on acuity (4 observers), acuity plotted against foot-candles of light normal to the surface of test-object.

Data for Fig. 1.

Intensity (foot-candles)	Acuity
0.001	0.140
0.005	0.2075
0.010	0.2655
0.015	0.381
0.02	0.483
0.05	0.615
0.10	0.8245
0.20	1.028
0.40	1.158
1.00	1.350
2.00	1.611
3.00	1.743
5.00	1.9385
10.00	1.973
20.00	2.097

In another series of experiments the most practiced observer was selected for a comparison of the effect of change of intensity of light on the eye with normal refraction and the same eye made slightly astigmatic in the following ways,—by a + 0.12 diopter cylinder; a + 0.25 diopter cylinder; a + 0.25 diopter cylinder

with a correcting cylinder five degrees off axis; and a $+0.25$ diopter cylinder with a correcting cylinder ten degrees off axis. Refraction defects of this type and magnitude are of very common occurrence. Even in case of the corrected eye the correction

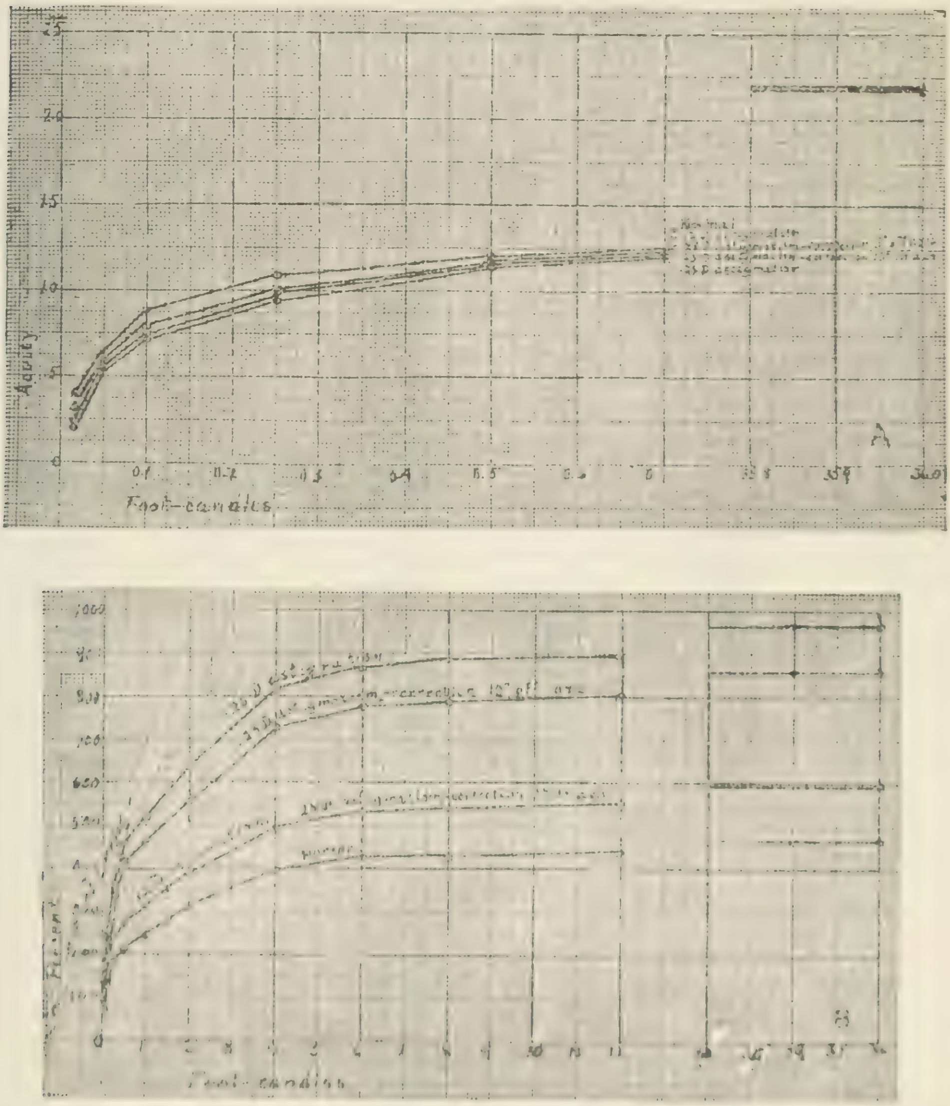


Fig. 2.—Showing the effect of increase of intensity of light on acuity for eye with normal refraction and same eye made slightly astigmatic: A, acuity plotted against foot candles; B, percentage gain in acuity plotted against foot candles.

for high astigmatisms is frequently off from 0.12-0.25 diopter in amount; and for low astigmatisms, 0.12 diopter in amount; and from 5-20 degrees in the placement of the correction. Artificial astigmatisms were chosen for this work in order that we might

know the exact amount and location of the defect and have a comparison of the effect on the same eye in the normal and defective condition. They were not chosen with the belief that they are the exact functional equivalent of the natural astigmatisms. We are too strongly impressed with the possibility that the astigmatic eye may progressively acquire some power to compensate for its defect to be of this opinion. The eye was pre-sensitized by 30 minutes of adaptation to each illumination. The brightness of pre-exposure and surrounding field was the same as that of the test surface. The reflection coefficient of the test surface was 78 per cent. The intensities of illumination were 0.015, 0.05, 0.10, 0.25, 0.50, 1.00, 1.50, 2.00, 4.00, 6.00, 8.00, 12.00 and 36.00 foot-candles normal to the test surface. The results are shown in Fig. 2A and Fig. 2B. In Fig. 2A, acuity

Data for Fig. 2A.

Intensity (f. c.)	Acuity				
	Normal	.12 D. astig.	.25 D. astig.-cor. 5° off axis	.25 D. astig.-cor. 10° off axis	.25 D. astig
0.015	0.386	0.316	0.316	0.226	0.203
0.050	0.649	0.598	0.596	0.571	0.531
0.10	0.877	0.775	0.775	0.754	0.719
0.25	1.08	1.012	1.004	0.985	0.941
0.50	1.20	1.184	1.184	1.168	1.132
1.00	1.339	1.300	1.294	1.268	1.258
1.50	1.464	1.424	1.424	1.389	1.377
2.00	1.587	1.548	1.554	1.509	1.496
4.00	1.918	1.886	1.895	1.876	1.865
6.00	2.033	1.998	2.012	1.978	1.955
8.00	2.044	2.030	2.030	2.009	1.992
12.00	2.087	2.065	2.065	2.040	2.022
36.00	2.200	2.190	2.190	2.167	2.158

Data for Fig. 2B.

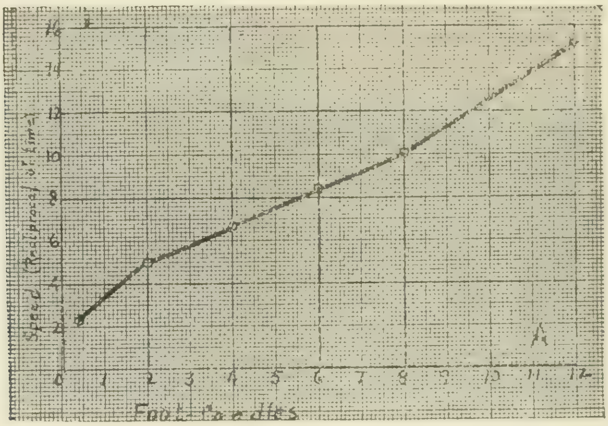
Intensity (f. c.)	Per cent.				
	Normal	.12 D. astig.	.25 D. astig. cor. 5° off axis	.25 D. astig. cor. 10° off axis	.25 D. astig.
0.015	——	——	——	——	——
0.050	68.13	89.24	88.61	152.65	161.58
0.10	127.20	145.25	145.25	233.63	254.18
0.25	179.79	220.25	217.72	335.84	363.55
0.50	210.88	274.68	274.68	416.81	457.64
1.00	246.89	311.39	309.49	461.06	519.70
1.50	279.27	350.63	350.63	514.60	578.33
2.00	311.14	389.87	391.14	567.70	636.95
4.00	396.89	496.84	499.68	730.09	818.72
6.00	426.68	532.28	536.71	775.22	863.05
8.00	429.53	542.41	542.41	788.94	881.28
12.00	440.67	553.48	553.48	802.66	896.06
36.00	469.95	593.04	593.04	858.85	963.05

is plotted against foot-candles and in Fig. 2 B percentage gain in acuity with increase of illumination is plotted against foot-candles.

THE EFFECT OF INTENSITY OF LIGHT ON SPEED OF DISCRIMINATION.

For the case of normal refraction this work was done on seven observers. Two of these observers were selected for a comparison of the effect on the normal eye and the same eye given a slight refraction defect. Slight astigmatisms were produced by a + 0.12 diopter cylinder, and by a + 0.25 diopter cylinder with a correcting cylinder five degrees off axis. Again the test-object was a broken circle, the opening of which subtended a visual angle of 1.147 minutes of arc, at the eye of the observer 6 meters distant. The circle was mounted at the center of a graduated rotating dial. Exposures were made by means of a tachistoscope somewhat similar to that devised by us for the Air Service of the U. S. Army, later supplied to the Japanese Army, furnished with only one set of exposure discs rotating in front and as close as possible to the test-object. On the front surface of these discs in line with the observer's eye and the test-object was placed a fixation cross in order that the exposure might begin with the eye in approximate adjustment for the test-object. The determinations were made at 0.4, 2.0, 4.0, 6.0, 8.0 and 12.0 foot-candles of light normal to the surface of the test-object. The reflection coefficient of the test surface was 78 per cent. The angle of incidence of light on the test surface was kept constant for all illuminations. The eye was allowed to adapt to each intensity of light through a 30-minute practice series provided with proper rest periods. In the final series for the eyes with normal refraction eight positions of the test-object were used,—up, down, right, left, and the four 45-degree positions. For the eyes with the refraction defect, the same number of exposures were given to the test-object but only four positions were used for the opening in the circle, these midway between the meridian of the astigmatism and the normal meridian. This was done in order that each position should set as nearly as possible the same task for the resolving power of the eye.

The average results for the seven observers for normal refraction are shown in Fig. 3A. The results for the two observers



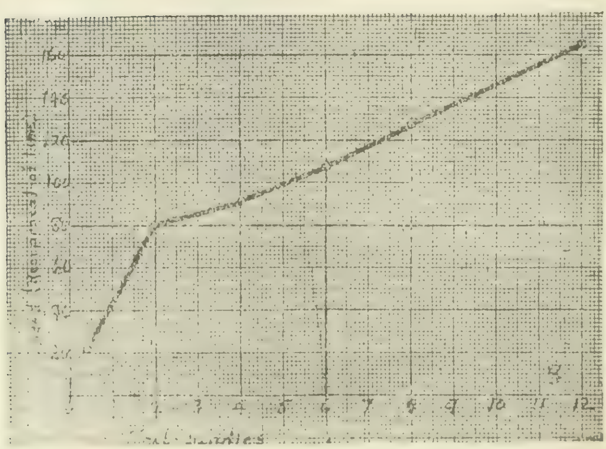


Fig. 3.—Showing effect of increase of intensity of light on speed of discrimination for eyes with normal refraction: A, visual angle 1.15 minutes of arc (7 observers); B, visual angle 2.49 minutes of arc (2 observers, selected from the 7).

Data for Fig. 3A.

Intensity (f. c.)	Speed
0.4	2.285
2.0	4.985
4.0	6.369
6.0	8.403
8.0	10.040
12.0	15.152

Data for Fig. 3B.

Intensity (f. c.)	Speed
0.4	21.854
2.0	80.128
4.0	91.117
6.0	106.818
8.0	126.790
12.0	165.043

with normal refraction and with the two types of refraction defect are shown in Fig. 4 A and Fig. 4 B. In Figs. 3 A and 4 A

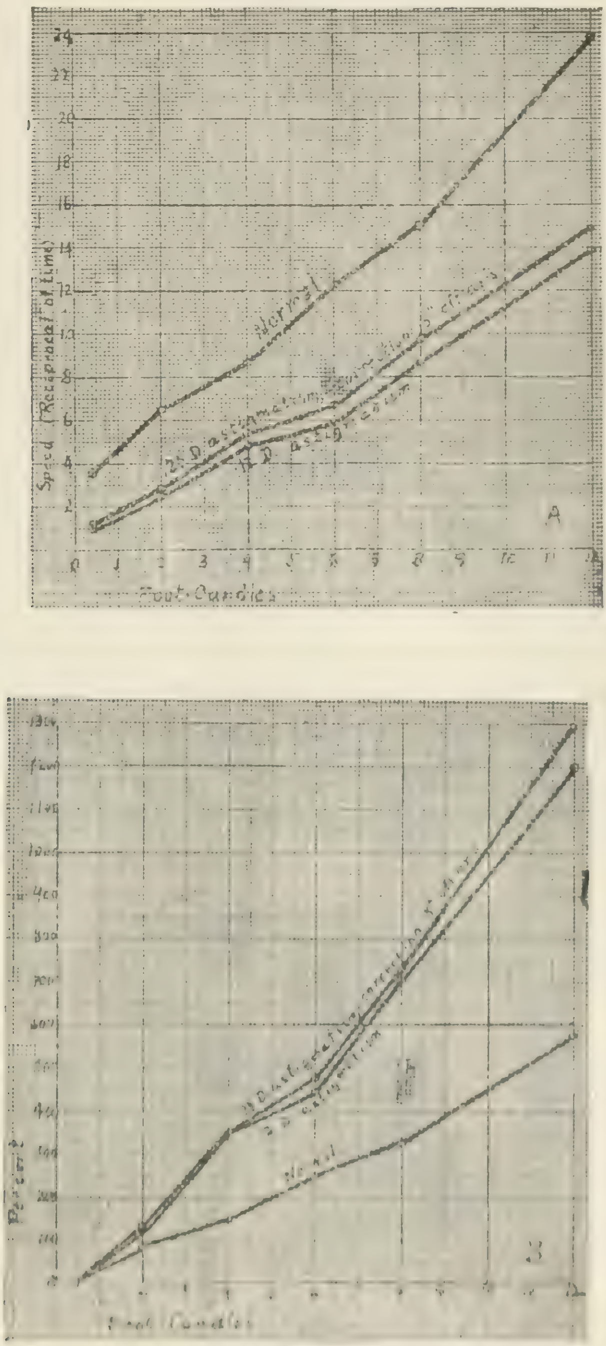


Fig. 4.—Showing the effect of increase of intensity of light on speed of discrimination (2 observers) for eyes with normal refraction and same eyes made slightly astigmatic: A, speed of discrimination plotted against foot-candles; B, percentage gain in speed of discrimination plotted against foot-candles.

	Data for Fig. 4A.			Data for Fig. 4B.		
	Speed			Per cent.		
Intensity (f. c.)	Normal	.25 D. astig. cor. 5° off axis	.12 D. astig.	Normal	.25 D. astig. cor. 5° off axis.	.12 D. astig.
0.4	3.525	1.188	1.074	——	——	——
2.0	6.508	2.768	2.476	86.22	124.92	130.10
4.0	8.654	5.398	4.848	146.49	351.53	351.11
6.0	12.274	6.757	5.892	248.80	472.88	448.73
8.0	15.046	9.717	8.662	327.59	727.15	706.68
12.0	23.810	14.941	13.976	576.23	1296.65	1203.04

speed, (reciprocal of the minimum time in seconds required for the discrimination of the test-object) is plotted against foot-candles; and in Fig. 4 B percentage gain in speed with increase of illumination is plotted against foot-candles.

As was stated in the introductory paragraphs, the determination of the relation which the gain in speed with increase in illumination sustains to the size of the object or visual angle will be made the subject of a later investigation. However, in order to determine provisionally whether there is a gain in speed for the larger visual angles, an additional series of experiments was conducted on two of the seven observers employed in the former test, using a visual angle of 2.49 minutes of arc—a rough approximation of the visual angle subtended by the details in 10-point type at the conventional reading distance, 33 cm. (13 in.). The results of this investigation are shown in Fig. 3 B.

THE EFFECT OF INTENSITY OF LIGHT ON THE SPEED OF ADJUSTING THE EYE FOR CLEAR SEEING AT DIFFERENT DISTANCES.

Determinations were made of the time required to change the eyes from a position of exact adjustment for the clear seeing of the test-object at 20 cm. (7⅞ in.) to one at 6 meters (19 ft., 8 in.) and back again to 20 cm. (7⅞ in.) at 0.4, 2.0, 6.0 and 12.0 foot-candles of light normal to each of the three test-objects. The process measured included the change of adjustment from one of the near test-objects to the far object, the discrimination of the far object, the change of adjustment back to the other near object, and the discrimination of this object. The determinations were made with the apparatus devised by us for the Air Service of the U. S. Army for determining the speed of adjustment of

the eyes of aviators. For a description of the apparatus and method of using, references are given in the appended footnote.[5] Larger visual angles were used in these experiments because of the difficulty of getting a test-object small enough to subtend the smaller values of visual angle at the distance of the two near positions, 20 cm. (7⅞ in.). For the near objects the value was 2.6 minutes of arc, and for the far object 1.4 minutes of arc. Again an objective check was had on the correctness of the judgment, *i. e.*, the test-objects were mounted at the center of rotating dials the task for the observer being to indicate the direction in which the opening was turned.

In making the determinations the test-objects were carefully adjusted to the level of the observer's eyes, the far object in the median plane; the near objects on either side slightly farther apart than the interocular distance, their separation being just great enough not to obscure the view of the far object with either eye. Constancy of position of the observer's eyes was secured by biting a mouthboard in which the impression of his teeth had been previously made and hardened in wax. The far object was illuminated by a 100-watt frosted type B mazda lamp in a Beehive reflector, the changes in intensity being produced by change of distance and measured with an illuminometer with its test plate in the position of the test-object. The angle of incidence of the light on the test-object was kept the same for all illuminations. The near objects were illuminated by light reflected from the mat white screen which formed the back of the apparatus and through an oblong aperture in which the observer viewed the three test objects. The source of light was a tubular tungsten lamp installed in the horizontal in a plane midway between the screen and the near test-object so that the center of the filament was about 12 cm. (4¾ in.) above the two test-objects and equidistant from them. The lamp was provided with a tubular reflector in the circular wall of which was an oblong aperture equal in breadth to about one-third of the circumference of the tubular reflector. By rotating this reflector the angle of

[5] The Inertia of Adjustment of the Eye for Clear Seeing at Different Distances: A Study of Ocular Functions With Special reference to Aviation. *Trans. American Ophthalmological Society*, 1918, XVI, pp. 133-166; *American Journal of Ophthalmology*, 1918, I, pp. 764-776. The Speed of Adjustment of the Eye for Clear Seeing at Different Distances. *American Journal of Psychology*, 1919, XXX, pp. 40-61.

incidence of the light on the reflecting screen could be changed and the intensity of the beam reflected to the near test-objects varied by small amounts. As already stated the intensity of light on the far test-object was measured with an illuminometer with its test plate in the position of the test-object; the near test-objects were matched in brightness to the far object at the different intensities of illumination. Adaptation was allowed for each intensity of illumination during a preliminary practice series of 30 minutes provided with proper rest periods.

For the case of normal refraction two observers were chosen, normal both as to refraction and muscle balance. The refraction defect was produced by +0.12 diopter cylinders, axes 45 degrees in one eye and 135 degrees in the other. The results of these determinations are shown in Figs. 5 A and 5 B. In Fig.

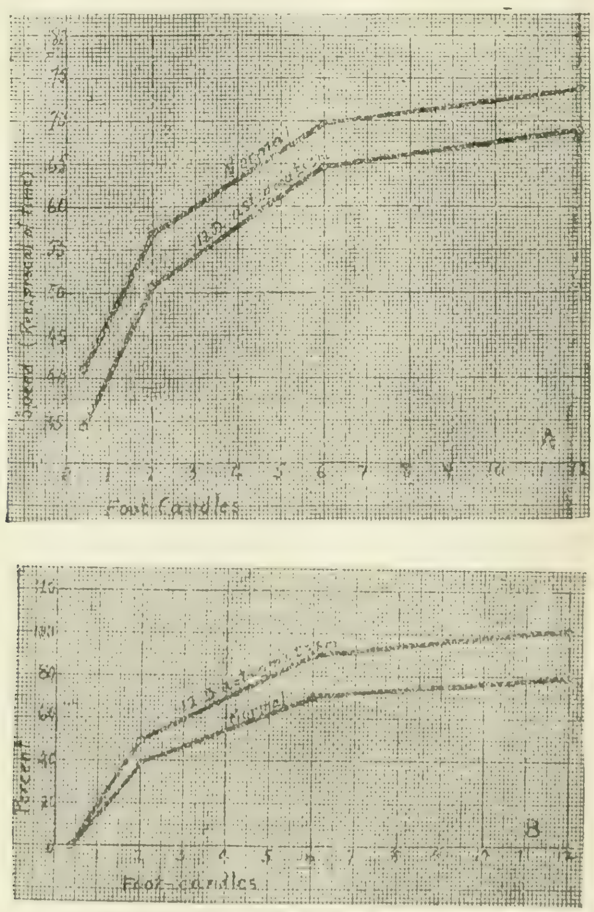


Fig. 5.—Showing the effect of increase of intensity of light on speed of adjustment of eye for clear seeing at different distances for eyes with normal refraction and same eyes made slightly astigmatic (2 observers): A, speed plotted against foot-candles; B, percentage gain in speed plotted against foot-candles.

Data for Fig. 5A.

Intensity (f. c.)	Speed	
	Normal	.12 D. astig.
0.4	0.411	0.344
2.0	0.568	0.508
6.0	0.697	0.645
12.0	0.737	0.689

Data for Fig. 5B.

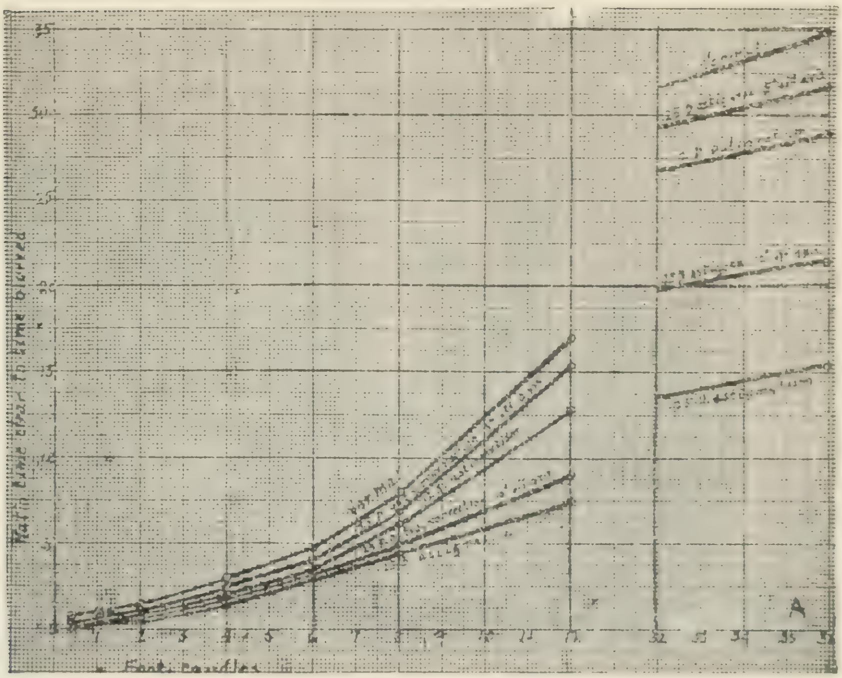
Intensity (f. c.)	Per cent	
	Normal	.12 D. astig.
0.4	——	——
2.0	38.67	49.32
6.0	70.25	89.02
12.0	79.74	101.90

5 A, speed is plotted against foot-candles; and in Fig. 5 B, percentage gain in speed with increase in illumination is plotted against foot-candles. While separate determinations were made of the time of adjustment from near to far plus the time of discrimination of the far object, and from far to near plus the time of discrimination of the near object, for brevity of presentation the effect only on the round trip is given in this paper.

EFFECT OF INTENSITY OF LIGHT ON POWER TO SUSTAIN CLEAR SEEING.

The determinations of power to sustain clear seeing were made at 0.4, 2.0, 4.0, 6.0, 8.0, 12.0 and 36.0 foot-candles of light normal to the test surface. The coefficient of reflection of the test surface was 76.5 per cent. For the case in which the visual angle was kept the same for the different illuminations, a value of visual angle had to be chosen which could be discriminated at all illuminations. A value was selected slightly greater than the minimum visual angle for the lowest illumination, namely, a value of 0.883 minute of arc. The test-object was the same as we have always used for the work on power to sustain clear seeing: the printed letters "li," the task being to resolve and hold clear the break between the dot and its stem in the letter i. The breadth of the break was 0.159 mm., and the visual angle subtended by the break at the observer's eye was, as already stated, 0.883 minute of arc. A record was made on a kymograph with a key, electromagnetic recorder and a Jacquet chronograph of the time the break could be discriminated in three minutes, the measure of the performance of the eye being expressed as a ratio of time seen clear to time seen blurred. It could also be expressed as time seen clear to total time of observation. There being no

objective check on the correctness of the judgment, its precision had to be checked up by the size of the mean variation as it is in photometry and other subjective performances in which an objective check is not possible. As in photometry, carefully tested and practiced observers are also needed. The work was done under well diffused daylight. This light was received from a skylight covering the entire ceiling of the room, beneath which was swung large diffusion sashes of ground glass filling the entire opening. The control of intensity was secured by two systems of thin white curtains running on spring rollers beneath the skylight, and a light-proof curtain. One of the systems of white curtains and the light-proof curtain ran lengthwise of the room; the other system of white curtains ran across the room. By means of the white curtains either small local or general changes could be produced in the illumination of the room and by means of the light-proof curtain larger changes could be produced ranging from full illumination to the darkness of a moderately good dark-room. The breadth of the light-proof curtain was equal to that of the room and it ran in a deep light-tight boxing. The white curtains were narrower and were made to overlap at the edges. These curtains ran on wire guides to prevent sagging or wrinkling. The walls of the room were mat white and the floor a light gray. The eye was pre-sensitized by 50 minutes of adaptation to each illumination. Constancy of position of the eye was secured by having the observer bite a mouthboard on which the impression of his teeth had previously been made and hardened in wax. The tests were made with normal refraction and for the same eyes made slightly astigmatic by a +0.12 diopter cylinder, a +0.25 diopter cylinder, a +0.25 diopter cylinder with a correcting cylinder 5 degrees off axis, and a +0.25 diopter cylinder with a correcting cylinder 10 degrees off axis. The axis of the cylinders used to produce the astigmatism was placed in each case at 90 degrees, the position of minimum effect on the detail to be discriminated. The results of these determinations are shown in Figs. 6A and 6B. In Fig. 6A, ratio of time clear to time



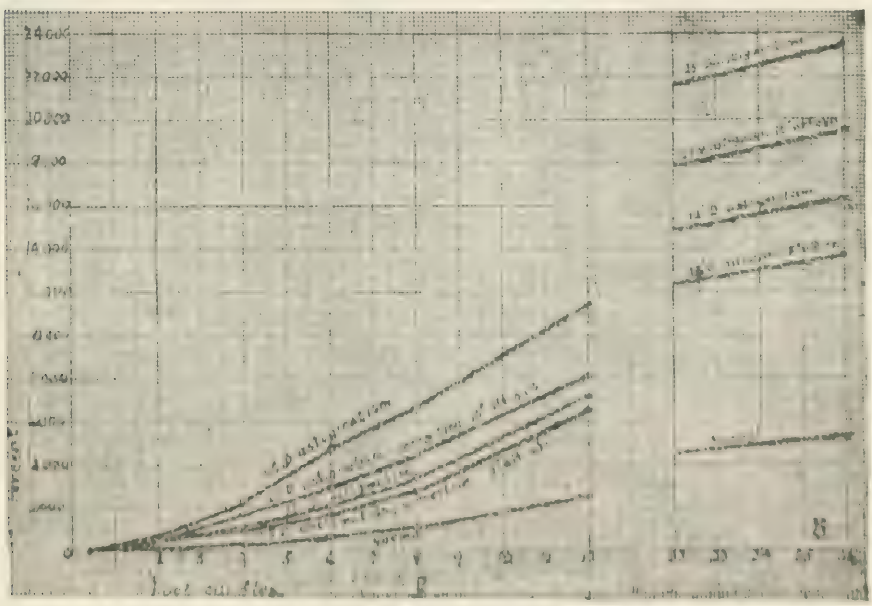


Fig. 6—Showing the effect of increase of intensity of light on the eye's power to sustain the clear seeing of the test object for 3 minutes for eye with normal refraction and for same eye made slightly astigmatic, visual angle (0.88 minute of arc) constant for all intensities of illumination: A, ratio time clear to time blurred plotted against foot-candles; B, percentage gain in ratio time clear to time blurred plotted against foot-candles.

Data for Fig. 6A.

Intensity (f. c.)	Ratio time clear to time blurred				
	Normal	.25 D. astig. cor. 5° off axis	.12 D. astig.	.25 D. astig. cor. 10° off axis	.25 D. astig.
0.4	0.65	0.23	0.18	0.11	0.065
2.0	1.50	1.31	1.07	0.70	0.45
4.0	3.00	2.60	2.16	1.90	1.57
6.0	4.81	4.14	3.74	3.39	3.19
8.0	8.00	6.82	6.20	5.00	4.46
12.0	17.00	15.36	12.85	9.00	7.57
36.0	35.00	31.73	29.00	21.50	15.35

Data for Fig. 6B.

Intensity (f. c.)	Per cent.				
	Normal	.2 D. astig cor. 5° off axis	.12 D astig.	.25 D. astig. cor. 10° off axis	.25 D. astig
0.4	——	——	——	——	——
2.0	130.80	469.60	508.0	536.40	595.40
4.0	361.50	1030.40	1126.10	1624.50	2315.40
6.0	640.00	1700.00	2023.30	2981.80	4804.60
8.0	1130.77	2865.20	3422.70	4445.50	6753.80
12.0	2515.38	6578.30	7201.10	8081.80	11547.70
36.0	5284.62	13695.70	16377.30	19445.50	23521.50

blurred is plotted against foot-candles, and in Fig. 6B the percenage gain in the ratio of time clear to time blurred with increase of illumination is plotted against foot-candles.

As we have already stated, for the case in which the visual angle was changed to sustain the same percentage value to the minimum at which the observer could just discriminate detail under the different intensities of illumination, there was no measurable effect of increase of illumination on the power of the eye with normal refraction to sustain the clear seeing of its object for a period of three minutes. The values of these visual angles, 123 per cent. of the minimum, were 1.05, 0.775, 0.68, 0.597, 0.577 and 0.568 minutes of arc. These determinations were made at 0.4, 2.0, 4.0, 8.0, 12.0, and 36.0 foot-candles, in the same optics-room, and with the same conditions of distribution and control of illumination as those just described. When, however, the determinations were made with these same visual angles, at the

same intensities of illumination, by the same eye made slightly astigmatic a great deal of power was gained with increase of

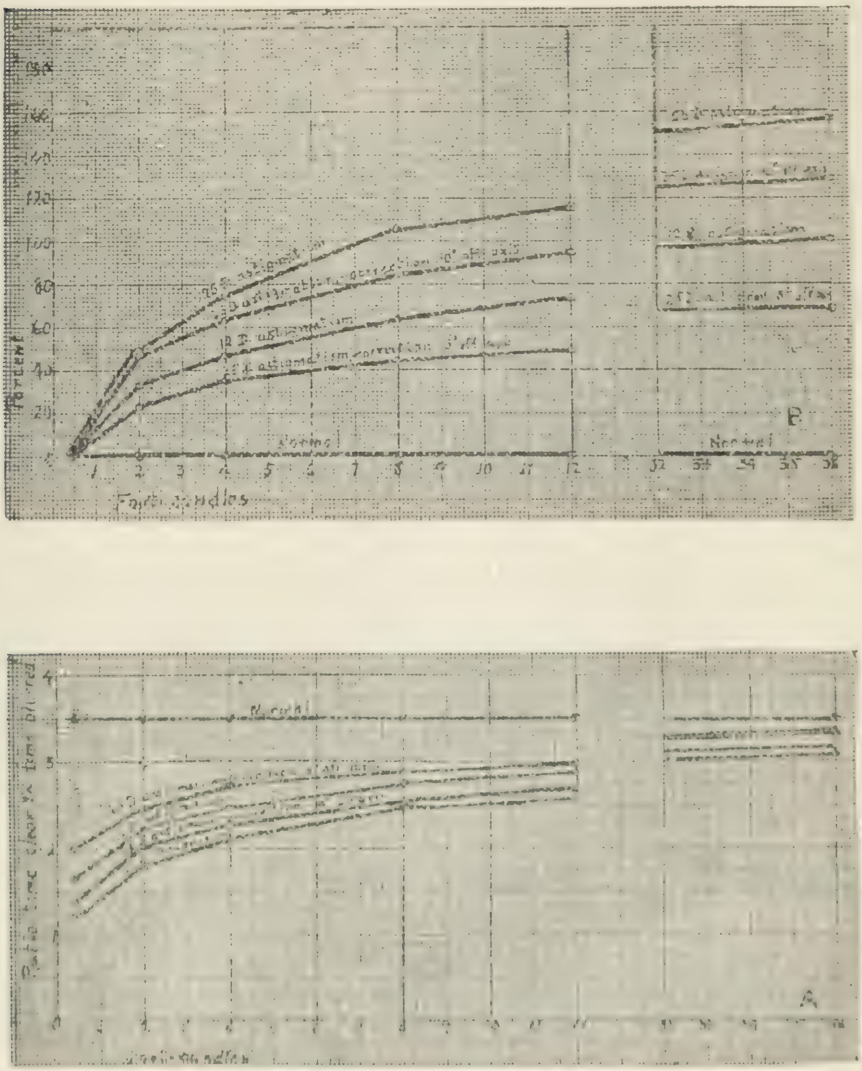


Fig. 7.—Showing effect of increase of intensity of light of the eye's power to sustain the clear seeing of the test-object for 3 minutes for eye with normal refraction and for same eye made slightly astigmatic, working visual angle changed to sustain the same percentage to the minimum visual angle at which the observer can just discriminate the test-object at the different illuminations: A, ratio time clear to time blurred plotted against foot-candles; B, percentage gain in ratio time clear to time blurred plotted against foot-candles.

illumination to sustain the clear seeing of the test-object. The astigmatisms were produced by a +0.12 diopter cylinder, a

+0.25 diopter cylinder, a +0.25 diopter cylinder with a correcting cylinder 5 degrees off axis, and a +0.25 diopter cylinder with a correcting cylinder 10 degrees off axis. The axis of the cylinder used to produce the astigmatism was placed in each case at 90 degrees. The results of these determinations are given in Figs. 7A and 7B. In Fig. 7A, ratio of time clear to time blurred

Data for Fig. 7A.

Intensity (f.c.)	Ratio time clear to time blurred				
	Normal	.25 D. astig. cor. 5° off axis	.12 D. astig.	.25 D. astig. cor. 10° off axis	.25 D. astig.
0.4	3.50	2.00	1.68	1.38	1.20
2.0	3.50	2.47	2.23	2.03	1.80
4.0	3.50	2.71	2.47	2.26	2.09
8.0	3.50	2.89	2.75	2.55	2.47
12.0	3.50	2.99	2.89	2.69	2.60
36.0	3.50	3.36	3.36	3.16	3.09

Data for Fig. 7B.

Intensity (f. c.)	Per cent.				
	Normal	.25 D. astig. cor. 5° off axis	.12 D. astig.	.25 D. astig. cor. 10° off axis	.25 D. astig.
0.4	——	——	——	——	——
2.0	0	23.50	33.10	47.10	49.60
4.0	0	35.50	47.40	63.70	74.40
8.0	0	44.25	64.10	84.64	105.80
12.0	0	49.65	72.10	94.93	116.30
36.0	0	68.00	100.40	129.00	157.50

is plotted aaginst foot-candles; in Fig. 7B, percentage gain in ratio of time clear to time blurred with increase in illumination is plotted against foot-candles. This latter series of experiments serves merely to give an additional comparison of the effect of increase of intensity of light on the power of the eye to sustain clear seeing when normal and slightly abnormal in refraction, with the visual angle and all other external conditions of seeing made the same for each.

For various obvious reasons the foregoing curves were not all plotted on the same scale, nor was the same number of observers used throughout. In order to make possible a comparison of the effect of changes of intensity of illumination on the different

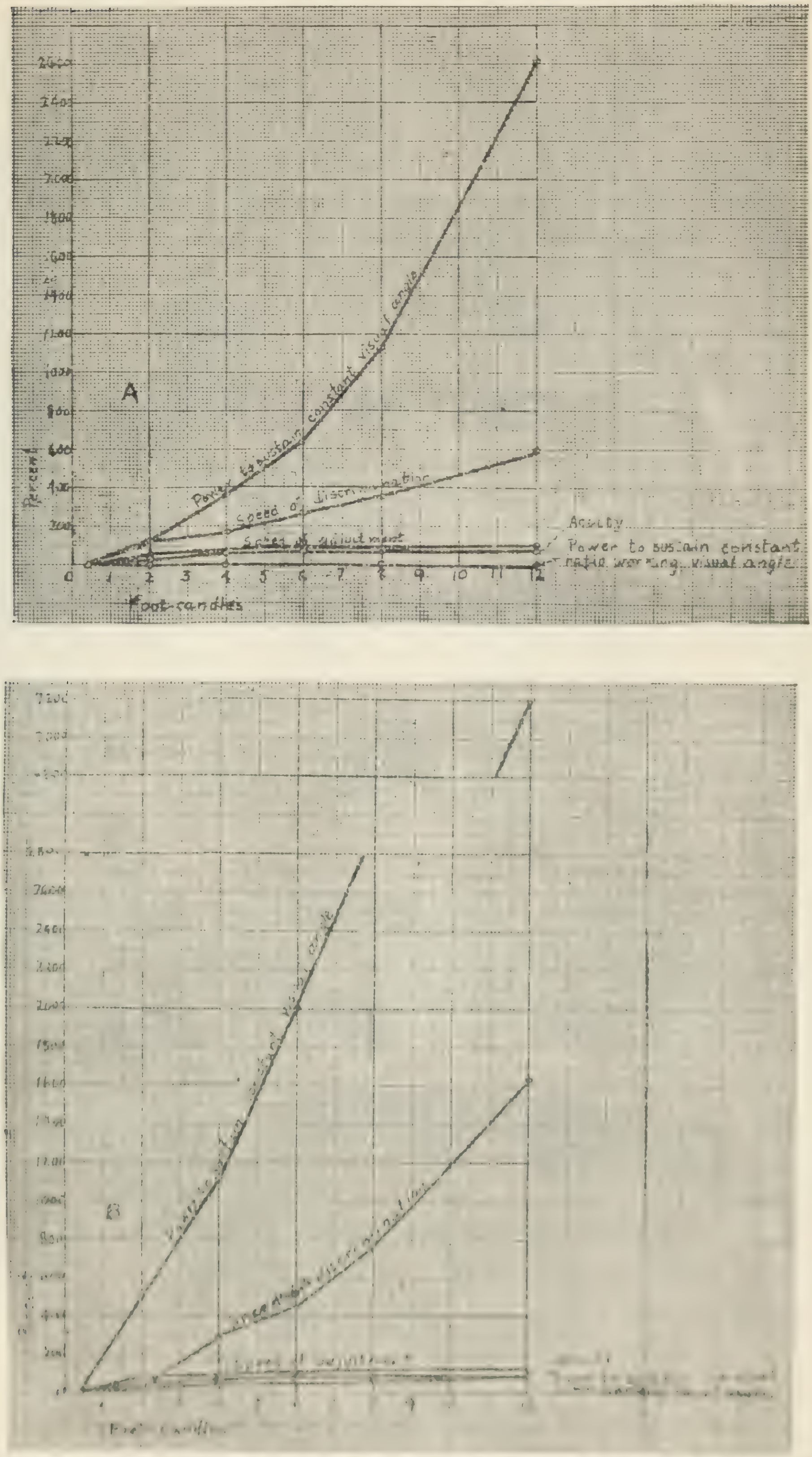


Fig. 8.—Showing percentage gain with increase of illumination in all of the functions tested, plotted to the same scale: A, eyes with normal refraction, B, same eyes made slightly astigmatic.

Data for Fig. 8A.

Intensity (f. c.)	Per cent. Acuity	Speed of discrimination	Speed of adjustment	Power to sustain acuity, visual angle constant	Power to sustain acuity, constant ratio working visual angle to min. visual angle
0.4	——	——	——	——	—
2.0	35.41	136.30	53.70	130.8	0
4.0	63.65	176.41	——	361.5	0
6.0	73.84	266.24	91.54	640.0	0
8.0	74.59	350.72	——	1130.77	0
12.0	77.99	597.61	100.81	2515.38	0

Data for Fig. 8B.

(f. c.)	Per cent. Acuity	Speed of discrimination	Speed of adjustment	Power to sustain acuity, visual angle constant	Power to sustain acuity, constant ratio working visual angle to min. visual angle
0.4	——	——	——	——	——
2.0	43.07	32.62	72.78	508.00	33.10
4.0	74.56	292.86	——	1126.10	47.40
6.0	84.66	428.71	111.57	2023.30	——
8.0	87.62	765.75	——	3422.70	64.10
12.0	90.85	1631.51	125.37	7201.10	72.10

functions *under the conditions tested,* Figs. 8A and 8B are given in which the curves are all plotted on the same scale and represent the results of the same observer. Fig. 8A shows the effect on the eyes with normal refraction and Fig. 8B on the same eyes made slightly astigmatic by a +0.12 diopter cylinder.

It has been popularly supposed that the eye by adaptation changes its sensitivity to compensate for changes of illumination over a very wide range. So it does, but the compensation is by no means complete, so far as the effect on clear seeing is concerned, more particularly with regard to the very important aspects: speed of discrimination, speed of change of adjustment for clear seeing at different distances, and power to sustain clear seeing. The eye has developed its functional powers under the higher intensities which characterize daylight illumination. It is perhaps not surprising, therefore, that it should have its highest functional efficiency under these intensities.

With reference to the difference between the amounts of light to which we are accustomed for daylight and artificial illumination the writers recall having been asked to measure the daylight illumination of the magazine room of a college library which was about to be condemned because of insufficient intensity of illumination. The measurements showed a range of 5-15 foot-candles, vertical component, in various parts of the room on a medium bright day. Another striking illustration of the difference of intensity found in daylighting and artificial lighting, as it impresses itself by experience, is to pass suddenly from daylight to artificial illumination while reading on a train as it enters a tunnel. Experiences of this sort help us to realize how much we rely on adaptation to bring the eye up to daylight efficiency when working under artificial illumination of the intensities ordinarily employed.

There is danger also of being misled by results and curves showing the change in retinal sensitivity by adaptation. Acuity changes slowly with change in retinal sensitivity. For data showing the change in acuity with adaptation, the reader is referred to *Transactions of the American Ophthalmological Society*, 1919, XVII, and the *American Journal of Opthalmology*, 1920, III, pp. 408-417.

APPENDIX.

In paragraph numbered 6, under the beneficial effects of increase of intensity, we stated that, using the method for testing fatigue employed in all of our former work, no difference in effect could be found for reading for three hours from uniform type and paper under well diffused daylight illumination with 0.4, 2, 4, 6, 8, 12 and 36 foot-candles of light on the reading page when the eye was adapted for fifty minutes to each intensity of illumination prior to beginning the test. In view of the results obtained with the preceding tests for increase of intensity of illumination this result may cause some surprise. In comparing this result with the others the following points should be borne in mind: (1) The visual angle subtended by ordinary print at the reading distance 33 cm.) is large. A different result would doubtless have been obtained if fine print or a smaller visual angle had been used. (2) The visual angle subtended by the test-object used in

the 3-minute record before and after the 3-hour reading period was changed to sustain approximately the same ratio of time clear to time blurred for the fresh eye for each illumination used. That is always done in this test so as to get as nearly as possible the effect of the reading alone. (3) There is no guarantee that the eye read with the same speed and accuracy at the different illuminations, therefore no guarantee that the eye did the same amount and quality of work at the different illuminations. There doubtless would be a tendency for the eye to read more slowly under the more difficult conditions of work although the intention of the observer was to read at the same speed at all illuminations. Had it been possible to secure a feasible standardization of the features of speed and accuracy of work during the three-hour period, the test would doubtless have been rendered more sensitive for picking up small differences in the favorableness of the lighting conditions employed in this and all of our former work. That is, a strict standardization of the speed and accuracy of performance during the working period would doubtless have given even a greater difference in result for the different lighting conditions, during the past several years of work, than were obtained. So far we have not found it feasible to incorporate the testing of the features: speed, accuracy and the power to sustain in one and the same test. We have instead tested together speed and accuracy and power to sustain and accuracy; there has, however, been no strict standardization of speed and accuracy during the period of work in the fatigue test.

DISCUSSION.

LOUIS BELL: We owe a debt of gratitude to the authors for putting before us so clearly some concrete measurements regarding the effect of illumination. These things are, in a way, a matter of general knowledge, but precise measurements have been comparatively scarce. The thing I wish especially to point out in connection with this paper is that the authors I think rather understate the case. They certainly have not erred in the way of exaggeration.

They used the simplest possible test, the broken circle, which formerly was used to test people who couldn't read, but, as mentioned, it leads to somewhat slightly higher values of acuity all

along the line than the more highly complicated tests. Hence, for all tests like the reading test, it would run a bit lower all along the line and consequently the effect of increasing illumination would be even more conspicuous.

Further, I think it is quite probable—I will trust the authors' judgment on that—that the same fact, the simplicity of the object would tend to lessen, rather than to increase, the astigmatic difficulties found in the human eye. One-half the people of the world are astigmatic, and three-quarters of them don't know it, consequently, these vital facts regarding the need of illumination stand out with exceptional force. I have noticed it many a time in dealing with illumination where bodies of people were concerned, for instance, in a stenographic room. It is almost impossible to get light enough for a stenographic room, partly, I think, because the work requires much light, also because as a rule, the stenographers will not wear glasses.

I think the percentage of slight errors in refraction runs high and so all through the public with whom the illuminating engineer has to deal, he has to remember in the work shop, in the school, in the home, he has to consider a large number of eyes which have errors of refraction.

By standing in the rear of a school room, looking at the backs of the children, one will almost always be able to pick out the myopic, the astigmatic, and rather occasionally, hyperopia. These defects stick out plainly.

Consequently all that the authors have said I would emphasize as being rather conservative and understanding the differences which actually are found, especially with reading and other occupations where quick discrimination is needed, or where it is necessary to hold the discrimination, we have to go a little farther, as a matter of practice, than when we base our judgments on the simplest possible case.

S. E. DOANE: The authors have presented an important paper at an opportune time. Because of the trend of the times the lack of information on the subject is being felt. We have only recently learned to ask ourselves the fundamental question in connection with our various applications of light, to wit, how much light should this particular operation require? So important has this question become that at the next Convention or at a

Convention in the very near future we can well afford to give a whole day to the discussion of this one subject.

J. R. CRAVATH: I certainly want to second all that Dr. Bell and Mr. Doane have said regarding the value of this paper, especially to those who are on the firing-line, applying correct illuminating principles to actual practice. It has been very interesting to me to see how the results reported in the paper dovetail in with some of our previous knowledge. For example, we have known for a good many years that aged people generally desire much more light than young people, and constantly call for still more light, and we have accounted for it in various ways, but presumably it is due to their inability to focus properly or accommodate with the aged eye.

Then, too, Mr. Durgin's experiments in industrial plants showed that the work was very materially speeded up by increasing the average intensities to two or three times what was formerly considered good practice. The results given by the authors partly account for the observations that Mr. Durgin made and also for the stimulating effect of the higher intensities.

Some of the curves published by the early investigators on visual acuity mislead us in our early consideration of the intensities needed. These curves have been reproduced many times. They indicate that after reaching one foot-candle, for example, as in Fig. 1, in the authors' paper, there is very little improvement as the intensity is raised. The trouble was, we accepted those figures at their face value and did not inquire how they were obtained and to just what conditions they applied. The authors are making a closer analysis of the subject, and are finding many features not counted on before.

F. C. CALDWELL: The fact that curve No. 1 becomes horizontal at five or six foot-candles has served to mislead us in the past. However, all the other curves continue rising rapidly at 12 foot-candles and in Fig. 6, they are still moving up rather rapidly at 36 foot-candles, and hence it looks as if we may still be in practice far below the optimum value of the illumination.

A curious subject for speculation has occurred to me, may not the increasing demand for light, as one gets older, account, at

least in part, for the fact that there is an ever increasing demand for light. The illumination which was considered adequate twenty-five years ago will not do to-day. We who are getting older are calling for more light, and the younger generation coming along falls into the procession. Thus the demand for illumination intensity is ever upward.

G. S. MERRILL: With respect to the part of the paper dealing with the effect of the intensity of the light on the speed of discrimination, I would like to ask how the discrimination response was measured and ascertain something as to the absolute value of the time of response. In some tests with which I have been familiar the quickest response we could get was in the neighborhood of 3.75 per second. It is interesting to have some idea of the time-interval involved, and the amount of time that might be lost where illumination is not up to the point which will permit a firm, quick determination. How was the measurement made as to the average value of time?

EARL A. ANDERSON: In obtaining the very striking curves showing the improvement in efficiency of the eye with higher levels of illumination, the authors used a white paper background reflecting approximately 75 per cent. of the light. Hence there existed almost a maximum contrast between the black test figures on the white background. Considering this, it is apparent that remarkable as the results given in the paper are, even much higher illuminations would be indicated as desirable if the contrast between the test figures and background used was less. I wonder if the authors have made any tests with backgrounds less white, giving lesser contrasts, and which would correspond with conditions very commonly met with in certain classes of industrial lighting.

G. H. STICKNEY: Those of us whose experience is rather close to the practical fields of lighting are often conscious of the impracticability of reproducing working conditions in a laboratory test. While we are also conscious of the practical need of the laboratory determinations to establish fundamentals and to eliminate variables, we are prone to judge the laboratory conclusion in terms of practice before accepting them and applying them in

connection with installations. Thus some practical engineers have, in the past, had some friendly differences with the present authors as to the application of certain conclusions.

In reviewing this paper it has seemed to me that the conclusions given harmonize very closely with the practical observations of lighting in the field. And therefore, while I am not prepared to verify the data from the laboratory standpoint, I feel considerable confidence in the conclusions and the related data.

The paper further reenforces our confidence in our own conclusions and brings us some valuable additional information. I think practical men have not realized in the past the importance of providing unusually good lighting for aged or subnormal eyes. The paper represents a very valuable contribution.

NORMAN MACBETH: Referring roughly to Fig. 1, relating to acuity showing the necessity of 20 foot-candles secured with a test object having a coefficient of reflection of 58 per cent., had that test object been on a dark surface, the intensities would have increased by some 50 per cent. The statement is made that for ordinary illumination work, a fair acuity value for test objects is reached at 5 foot-candles, whereas, the real consideration is the object which one desires to see, and if that proves to have less than 78 per cent. reflection one naturally requires better illumination for it.

F. C. CALDWELL: During the past year the I. E. S. Committee on Education has taken as one of its functions the encouraging of research work along illumination lines among the colleges. There are certain problems of this sort where it is necessary or desirable to have a considerable number of at least fairly well trained observers. In a college can always be found a group of students who are intelligent and interested and have had some experience in observation, and thus problems of this sort lend themselves particularly to college research.

It would seem to me that the problem is so big and of such pressing interest that it might be desirable if all those who are interested in working along this line might get together and divide the work up so that unprofitable duplication would not be undertaken.

C. E. FERREE: It is quite obvious that many valuable points are brought out in the discussion which were not contained in the paper. Only a few of these points require comment.

I agree with Dr. Bell that the broken circle is a comparatively simple test-object and that still greater difference in result may be expected when the task imposed is the discrimination of a more complex object. The Committee on Standardization of Test-objects, Ophthalmological Section of the American Medical Association, 1916, for example, rated the Snellen letters with reference to their difficulty of discrimination in the following order: B, H, H, S, R, E, N, Z, D, P, F, Y, etc. Our remarks in the paper with regard to simple test-objects, however, were directed towards test-objects still simpler than the broken circle. We say, for example, "the effect of the slight distortions present in the refracting action of nearly every eye, which confuse the discrimination of complex test-objects, is lost in the simple test-object." These distortions are by no means lost on the broken circle as any one can testify who has worked with the broken circle near the threshold of discrimination, more particularly at low illuminations. Low astigmatisms and slight irregularities of refraction not classed as astigmatisms which do not affect the discrimination of parallel lines, distort the form of the broken circle and appear particularly at low illuminations, to cause a break to occur also at some other point than where the break actually is in the test-object. In making this and other comments on the comparative merits of test-objects we had in mind in particular such test-objects as parallel lines. In using parallel lines as the test-object one should bear in mind that his results overestimate the ability of the eye to discriminate the more complex objects which form the greater part of our work, and that test-objects so simple in form have a comparatively low sensitivity for the detection of low astigmatisms and for determining the exact amount and placement of their correction. What is needed as a test-object is one that gives fine changes in visual angle and is sufficiently complex as to form to tax simultaneously the resolving power of the eye in several meridians. So far such a test-object has not been provided.

The following are some of the reasons which influenced our choice of the broken circle for this work. (a) It is by adoption

the international test-object. (b) We wished to use a test-object to the accuracy of discrimination of which we could apply an objective check, *i. e.*, the opening of the circle could be turned into different meridians and the observer be required to tell in what direction the opening was turned. This could have been done also with the letter E, but we have shown repeatedly in previous work that smaller differences in acuity can be picked up with the broken circle than with the letter E. The massing of black on one side of the letter E due to its vertical bar or backbone enables the observer to judge the direction in which the parallel bars point even when the parallel bars themselves can not be separated or resolved by the eye. (c) The effect of the slight distortions mentioned above confuses the discrimination of the broken circle more than that of the letter E.

In answer to Mr. Merrill I would say that our exposures were made by our sectored disc tachistoscope giving single exposures and driven by a compound pendulum with adjustable weights. The broken circle was mounted at the center of a rotating graduated dial on the level of the eye, behind the vertical disc and as near to it as possible. Prior to the exposure the dial was set to make the opening of the circle point in a given direction, then the exposure was made, and immediately after the observer reported verbally the direction in which the opening of the circle pointed. For the normal eye eight positions of the opening were used: up, down, right, left, and the four 45° positions. The ability to tell in a given percentage of the eight cases in which of these positions the opening was placed was taken as the criterion of the observer's ability to discriminate the test-object for a given length of exposure and intensity of light. Thus the *discrimination time* alone was measured.

I judge from the order of magnitude of Mr. Merrill's results that his observers indicated the discrimination by a reacting movement, such as the pressing of a key to operate a chronoscope. If so, he was measuring both the discrimination time and the time required for the reacting movement. This would be very much longer than the discrimination time which we measured alone. The quantity measured by Mr. Merrill is ordinarily classed as the reaction time to visual stimuli. Since it measures both the time of discrimination and of the reacting movement, the reaction

time experiment is an insensitive procedure to employ when the problem is to pick up differences in condition which affect the discrimination time alone. The time required to perform this movement is much longer, for all but low intensities and small visual angles, than is required to make the discrimination, and is probably very little if any affected by intensity of light and other optical conditions which affect the time of discrimination. It therefore remains a more or less constant component which masks in the total result the changes in the variable component which it is our problem to detect. Moreover, the reaction time experiment is subject to the influence of a greater number of extraneous variable factors which serve to give it a higher mean error than the discrimination time experiment. I was very much surprised to note that during the war the reaction time experiment was used in many cases where the important quantity to measure was the discrimination time alone. In fact I know of no case where use was made of the measurement of the discrimination time alone.

I have stated that I judge that Mr. Merrill used the reaction time experiment because of the order of magnitude of his results which are in close agreement with those obtained by others who have used the reaction time method. Lange, for example, found that the reaction time to visual impressions (simple light impressions) when the attention was directed to the sensation rather than to the reacting movement was 0.29 sec.; when the attention was directed to the reacting movement, it was 0.113 sec. When the attention was directed to the sensation the reaction time is found to be longer than when directed to the reacting movement. The first type of reaction has been called the sensory reaction; the second the motor reaction. The "motor" reaction has the smaller mean variation. Differences in result are no doubt due in part to the difficulty of maintaining the constancy of the type of reaction; there seems to be a tendency varying with the individual reactors for the "sensory" to pass over into the "motor" type. The individual differences found may also be due in part to a natural tendency to direct the attention in the one way or the other.

We have not conducted tests under the conditions mentioned by Mr. Anderson, namely, with the letters on grounds of a different coefficient of reflection. Since the reflection coefficient of the

black is low, I should judge that the effect of changing the reflection coefficient of the ground from 78 to 39 per cent., for example, would be very nearly the same as reducing the incident light by one-half. We should think, therefore, that Mr. Anderson is not far from correct in suggesting that much higher intensities of light than our results show, are indicated as desirable when the contrast between the object viewed and its background is less than employed by us, as is the case with many of the working conditions under which the eye is used. The point raised by Mr. Macbeth is substantially the same as that raised by Mr. Anderson and does not therefore require separate consideration.

After many years we are glad to have reached a closer agreement with Mr. Stickney and others with whom we have had friendly differences. From this point of view we can only regret that we did not make the present study eight years ago instead of the ones made by us around that time. However, to us the most pressing need at that time seemed to be to bring to bear whatever pressure we could to create a sentiment against harmful glares. Of the distribution factors, evenness of distribution of light seemed to be the one on which attention was concentrated. Reflectors were being designed and widely used which distributed the light evenly but which introduced glare surfaces into the field of view which were exceedingly fatiguing and harmful to the eye. At that time Cravath, Sweet and others talked of the harmful influence of glare, and a still smaller group urged the importance of brightness measurements, to audiences which also did not always agree with them. That condition now, we are glad to say, is greatly changed. All agree that glare must be controlled, and intelligent effort is being directed towards accomplishing its control. It seems safe now to indicate the need of more light and to hope for obtaining it without introducing harmful glares into the field of view. As Mr. Doane has pointed out, the time is opportune for turning our attention to the study of intensity and to the means of securing the more favorable higher intensities without sacrificing the needed control of the distribution factors.

It is fortunate too that the study of the effect of variations of intensity of light afforded an especially convenient, feasible and suggestive starting point for the testing of other functions of importance to the working eye. From the standpoint of method

and technique fatigue has ever been a difficult thing to test in a way that carries understanding and conviction to the lay mind. In testing effects on speed, however, one does not start with that handicap. Also as a function of phenomenon it is more easily understood. These facts, we believe, have also had something to do with the friendly differences mentioned by Mr. Stickney. It is our hope to extend the testing of the functions added in this paper to the study of the effect of color value, evenness of surface brightness, etc., in order that we may further enlarge in these directions our knowledge of the eye's proficiency in relation to the conditions of lighting under which it works.

MEASUREMENT OF REFLECTION FACTORS.*

BY C. H. SHARP AND W. F. LITTLE.

The importance of the measurement of reflection factors, particularly factors of diffuse reflection, has long been recognized and a good deal of work has been done in the field. Until quite recently, however, the matter has been in a rather unsatisfactory state and the values given have been subject to much uncertainty. The introduction of the integrating sphere put at the disposal of photometrists an evident means to use in such measurements,[1] but for the most part measurements so made have been purely relative, that is, they have been expressed in terms of a standard surface the reflectivity of which has been determined by other means, an operation which until recently has not been carried out with a satisfactory degree of precision. For such a service commercial magnesium carbonate block has been extensively used as being a convenient substance and the one which apparently has the highest reflection factor of any ordinary material. Quite generally, too, the value of the reflection factor of this substance has been taken as 0.88 in accordance with data presented by Nutting[2] before this Society.

Recently evidence has been accumulating that Nutting's value of reflection factor of magnesium carbonate was considerably too low. For example, Rosa and Taylor[3] found for Keene's cement with which the 88-inch integrating sphere at the Bureau of Standards was coated, a reflection factor of 0.92. Benford[4] and Taylor[5] using methods identical in principle, have found a value for this substance running from 0.97 to 0.99. Benford has shown that by correcting Nutting's original results for the error of his instrument, a value of 0.97 is obtained, and Taylor has confirmed his own sphere values by the integration of distribution

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] "*Illuminating Engineering Practice,*" I. E. S. Lectures at University of Pennsylvania, p. 128.

Journal Franklin Institute, Vol. 181, p. 99, 1916.

[2] TRANSACTIONS I. E. S., Vol. IX, p. 596, 1914.

[3] TRANSACTIONS I. E. S., Vol. II, page 453, 1916.

[4] *G. E. Review*, Vol. 23, p. 72, 1920.

[5] *Journal Optical Society of America*, Volume 479, 1920.

curves obtained by a point-by-point method. The method used by both of these experimenters is a new one giving absolute values, and depending upon two sets of measurements made with a sphere coated on the inside with the surface to be tested, one set with the sphere complete or nearly complete, and the other with a portion of the sphere removed, whereby the average reflection factor of the interior of the sphere is reduced in a measurable ratio.

An examination of the theory of the sphere has shown that its possibilities in the way of yielding absolute determinations of reflection factors have not been exhausted, but that there remains a still simpler method than Mr. Taylor and Mr. Benford have used. It shows also that use of the sphere may be extended to take care of the very important practical case where the reflecting body is not a perfect diffuser, but where it may be anything from a regularly reflecting mirror to a perfect diffuser, with any gradation of mixed reflection which may lie between, a phase of the problem which has hitherto received scant attention.

THEORY OF THE METHOD.[6]

If light is projected through a small aperture into the sphere in such a way as to form a small bright spot on its diffusely reflecting walls, this spot will give to all the rest of the sphere a uniform brightness; that is, the light flux reflected per unit area over all the surface of the sphere outside of the spot of light will be uniform throughout. If now we interpose between the spot of light and a small area on the sphere at which a brightness photometer looks, an opaque white screen, this screened test spot will receive an illumination from the rest of the sphere which is equal to the brightness of the rest of the sphere. Putting this into other words, the flux incident per unit area on the screened test spot will be equal to the flux reflected per unit area by the portions of the sphere outside the test spot and the illuminated spot. Now by definition, the reflection factor of the test spot is equal to the ratio of its reflected flux to its incident flux, that is, of its brightness to its illumination. Hence

[6] While the authors have worked out this theory independently, they are far from claiming priority for any of the individual steps. Reference should be made to the valuable papers by Cluney and Clark, TRANS. I. E. S., Volume X, p. 1, 1915, of Rosa and Taylor, *Ibid*, Volume XI, p. 453, 1916 and of Luckiesh, *Electrical World*, Volume LXIX, p. 958, 1917.

if the photometer observes first the brightness of the test spot when shaded by the screen, and second the brightness of the sphere wall outside the screened area, the ratio of these two brightnesses will be equal to the reflection factor of the test spot.

More formally stated, if B is the brightness of the sphere, E_s the illumination of a small screened area, and B_s the brightness of this area and r the reflection factor of the test spot, we have:

$$B = E_s \text{ and } r = \frac{B_s}{E_s} = \frac{B_s}{B}$$

Evidently, the portion of the sphere which forms the test spot should be removable so that over the aperture so formed any test sample can be placed, and a convenient arrangement should be introduced whereby the photometer can be rotated slightly so as to look alternately at the test spot and at a near-by portion of the sphere wall outside the screened area.[7]

If the test sample is a regularly reflecting mirror instead of one with a diffusing surface, the photometer will see by way of the mirror an unscreened portion of the sphere surface. The true brightness of this being B, the observed brightness, B_s, will be rB, where r is the reflection factor of the mirror, and again $r = \frac{B_s}{B}$. It follows that since under given sphere conditions an observation of the brightness of a test sample compared with the brightness of the sphere surface measures the reflection factor alike when the test sample has a diffusing surface and a regularly reflecting surface, such an observation must also give the reflection factor of a sample which gives mixed reflection with any relative amounts of diffuse and regular reflection.

Inasmuch as practically all surfaces with which we have to deal in illuminating engineering give a reflection of this mixed character, the last conclusion is of the very greatest practical importance. The procedure above outlined therefore gives a general solution of the problem of the measurement of reflection factors.

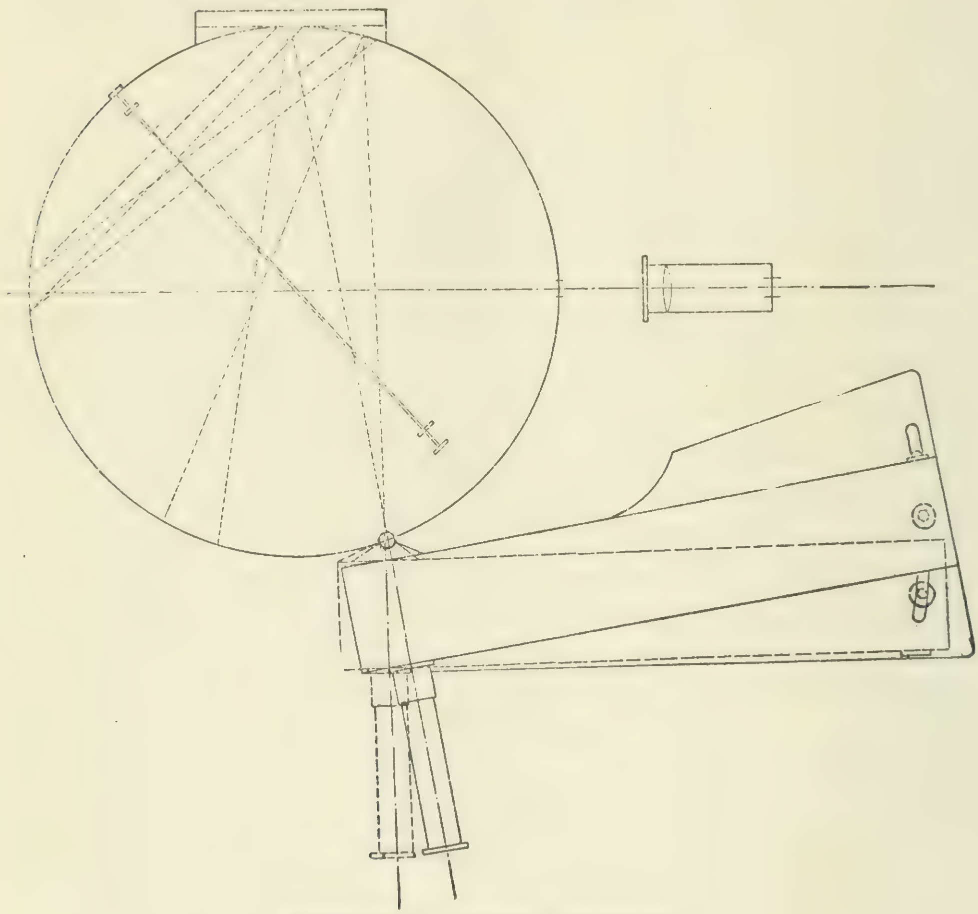
[7] An alternative arrangement is to substitute for the test sample a piece of metal painted like the rest of the sphere surface and to have the screen within the sphere so supported that it can be moved or rotated out of the way. In practice a plane mirror of known reflection factor may be substituted for the test sample and the brightness of the sphere wall determined by dividing the brightness so observed by the reflection factor of the mirror

Since the reflection factor of a plane mirror can be measured with high precision on a photometer bar with a point source of light, a ready and most valuable means is at hand to check the findings of the sphere. Inasmuch as only the ratio of photometric readings is involved in the determination of reflection factor, the photometer need not be calibrated but may be so adjusted as to give the best conditions as to color match and scale readings.

Obviously the above conclusions are subject to the physical limitations which are necessarily present. For example, no notice is taken of the departure from complete diffusivity of the sphere surface, nor of the influence of the screen in the sphere, nor of the area which the spot of light covers nor of the area of the apertures necessary for the admission of the beam of light and for the use of the photometer. It is clear that the apertures in the sphere should be as small as possible, as should also the spot of light within and the field of view of the photometer and the interposed screen. The size of the screen depends on the size of the spot of light and that of the photometer field. Any increase in the diameter of the sphere used tends to eliminate the influences of these disturbing factors provided that the area of the spot and of the photometer field are not increased in the same ratio as the sphere surface. To secure a small light spot with sufficient light to enable good photometric settings to be made requires a projection apparatus adapted to the purpose. To secure a small photometric field, the central spot of the Lummer Brodhun cube should be very small. For a large sphere a telephotometric arrangement might be used, that is, an objective lens might be attached to the ordinary photometer with the cube at or near its focus. Not only should the shading screen be as small as possible, but it should have as high a reflection factor as can be secured. No doubt a mathematical discusion could and should be made which would indicate the magnitude of the corrections involved in any case. It seems hardly advisable to delay this presentation for the purpose of such investigation, especially since the data presented below indicate that valuable practical results may be obtained with suitable apparatus even when such corrections are ignored, just as similar corrections are customarily ignored in the ordinary use of the integrating sphere.

DESCRIPTION OF APPARATUS.

In investigating the procedure experimentally, such apparatus as was available at the time at the Electrical Testing Laboratories was used. The sphere employed was of copper 12 inches (30 cm.) in diameter which was freshly painted so that its



Photometric apparatus arrangement.

interior surface might be as uniform as possible. The light was projected into the sphere by means of a special projection apparatus consisting of an automobile headlight lamp with condenser and objective lenses, all arranged so that the spot on the sphere wall had a diameter of about one inch (25 mm.). The photometer used had a Lummer-Brodhun cube with a very small central aperture so that its field of view on the opposite wall of the photometer was about ½ inch (13 mm.) in diameter. The test-plate was 90° from the spot of the light and the photometer nearly opposite the test-plate, its angle of view

being about 15° from the normal. This arrangement was chosen so that the points of the sphere wall observed by the photometer either when viewing a spot near the test surface or one on the opposite sphere wall, as is done when the test surface is a mirror, would be nearly symmetrically placed with respect to the spot of light. A small screen between the spot of light and the test surface was fastened to a slender rod with the end projecting so that the screen could be turned out of the way of the beam of light if so desired.

TEST RESULTS.

A number of surfaces were tested including blocks of magnesium carbonate, a plane glass mirror and a surface of milk glass roughened and standardized at the Bureau of Standards by Mr. Taylor's methods. The authors desire to express to Mr. Taylor their grateful recognition of his courtesy in preparing and standardizing this reference sample. The value given by the Bureau for its reflection factor coefficient is 0.84. The plane mirror was carefully standardized by repeated measurements on two different photometer bars and the average value for its reflection factor was found to be 0.83. A difficulty experienced, particularly in the earlier stages of the work, was in getting sufficient light in the sphere to enable good photometric settings to be made. During the later stages of the work the opening in the diaphragm admitting light which at first was only 6.5 mm. in diameter was increased to 10 mm., whereby the photometric conditions were materially improved. The test results are summarized in the following tables:

MEASUREMENTS OF REFLECTION FACTOR

TABLE I.

Reflection factors, assuming standard plate calibrated by the Bureau of Standards to be 0.84 (value assigned by Bureau of Standards).

Note: The light intensity low. Aperture of projection lamp 6½ mm. diameter. Diameter of illuminated spot approximately 18 mm. Readings somewhat uncertain because of low intensity.

Date	Series	Std. B. S.	Mirror	Mag. I.	Mag. II.	Mag. III.	Milk glass Polished	Milk glass Depolished	Sphere surface	Obs.
July 12	1	0.84	0.82	...	...	0.96	...	0.81	0.765	Z. N. C.
" 13	2	0.84	0.81	1.01	0.98	1.00	0.83	0.81	....	Z. N. C.
" 13	3	0.84	0.81	0.98	0.98	0.99	0.84	0.81	....	Z. N. C.
" 13	4	0.84	0.835	0.95	0.96	0.96	0.835	0.81	....	W. F. L.
" 13	5	0.84	0.83	0.95	0.95	0.96	0.83	0.82	....	Z. N. C.
	Avg.	0.84	0.821	0.973	0.968	0.974	0.834	0.812	0.765	

TABLE II.

Conditions same as Table I with projection lantern aperture enlarged to 10 mm., considerably increasing the illumination. Illuminated spot in the sphere approximately 25 mm. in diameter.

Date	Series	Std. B. S.	Mirror	Mag. I.	Mag. II.	Mag. III.	Milk glass Polished	Milk glass Depolished	Sphere surface	Obs.
July 13	6	0.84	0.81	1.00	0.99	1.00	0.835	0.805	0.75	Z. N. C.
" 13	7	0.84	0.80	0.98	0.96	0.96	0.82	0.78	...	W. F. L.
	Avg.	0.84	0.805	0.99	0.975	0.98	0.828	0.793	0.75	

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MEASUREMENTS OF REFLECTION FACTOR

TABLE III.

Spot of light on sphere wall decreased in area by shortening the distance between sphere and projection lamp.

Date	Series	Std. B. S.	Mirror	Mag. I.	Mag. II.	Mag. III.	Milk glass Polished	Milk glass Depolished	Obs.
July 15	8	0.84	0.83	0.99	0.99	1.01	0.81	0.79	W. F. L.
" 15	9	0.84	0.835	1.01	0.98	0.98	0.84	0.80	Z. N. C.
	Avg.	0.84	0.833	1.00	0.985	0.995	0.825	0.795	
	Grand Avg.	0.84	0.82	0.988	0.976	0.983	0.829	0.80	

TABLE IV.

Absolute method comparing screened test surface with unscreened sphere surface. Screen in sphere coated with magnesium carbonate.

Date	Series	Std. B. S.	Mirror	Mag. I.	Mag. II.	Mag. III.	Milk glass Polished	Milk glass Depolished	Obs.
					0.985	0.98	0.815	0.79	Z. N. C.
July 23	10	0.83	0.813		0.985	0.99	0.825	0.785	
								0.78	
							0.84	0.78	W. F. L.
" 23	11	0.84	0.842		0.99	0.98	0.85		
" 24	12	0.85	0.80		0.99	0.98	0.825	0.80	W. F. L.
" 24	13	0.83	0.828		0.985	0.98	0.815	0.77	W. F. L.
	Avg.	0.84	0.821		0.987	0.982	0.828	0.784	
	Grand Avg.	0.84	0.820		0.982	0.983	0.829	0.792	

Reflection Factor Assignments for Magnesium Carbonate.

Dr. Nutting	May, 1914	0.88
Mr. Taylor	Jan., 1920	0.99
Mr. Benford	Jan., 1920	0.97
E. T. L.	July, 1920	0.98

CONCLUSIONS.

A procedure has been worked out whereby the reflection factor of any surface, whether mat or glossy, may be measured by an absolute method. The results may be checked by the used of a calibrated plane mirror. The test results confirm the validity of the method. Further theoretical and experimental work, however, is necessary in ordei to determine the precisely best conditions as to size of sphere, lighting arrangements, photometric arrangements, etc., for cbtaining the highest precision in the use of this method, but for ordinary industrial purposes its validity is sufficiently proven by the test results given. The fact that measurements can be made on very small samples is an advantage of considerable importance in work of this character.

The values for the reflection coefficient of commercial magnesium carbonate block are in general agreement with those of Benford and of Taylor. As good an average value for this substance as in view of its variability it is practicable to fix would seem to be not far from 0.98, and it is suggested that tentatively at least this value be adopted. Reflection factors determined by relative methods based on Nutting's value for magnesium carbonate as a standard have evidently been too low, but they may readily be corrected to correspond to the suggested value for the standard by multiplying them by the fraction $\frac{98}{88}$.

DISCUSSION.

This paper was discussed in connection with the following paper by A. H. Taylor on an instrument for measuring reflection and transmission factors.

A SIMPLE PORTABLE INSTRUMENT FOR MEASURING REFLECTION AND TRANSMISSION FACTORS IN ABSOLUTE UNITS.*

BY A. H. TAYLOR.[1]

Early this year the author presented at the convention of the Optical Society of America, a paper giving a brief review of the methods which had previously been used in measuring reflection factors, and describing a new type of absolute reflectometer. The complete description of that instrument, with the derivation of the theory, is now available in a scientific paper of the Bureau of Standards.[2]

The instrument described at that time was very thoroughly tested, and was found to give correct results. However, certain precautions are necessary in its use, and the mathematical equations are somewhat complex. These factors might tend to limit its use in the hands of inexperienced observers, though not necessarily so, as a calibration curve can be calculated and drawn for use in routine measurements.

One of the extremely interesting and important developments in that work was the high reflection factor obtained for magnesium carbonate. Measurements by four absolute methods gave an average factor of 99 per cent. for a particular block of magnesium carbonate, whereas the previously accepted value was 88 per cent.

It has lately occurred to the author that a very simple reflectometer, based on one of the absolute methods employed in verifying the factor found for magnesium carbonate, could be constructed. It is the purpose of this paper to describe the new instrument, which, like the one previously described, is based on the principles of the integrating sphere, but which is operated in an entirely different manner.

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] Associate Physicist of the Bureau of Standards. This paper is published by the permission of the Director of the Bureau of Standards.

[2] B. S. Scientific Paper No. 391. Also *Journal of the Opt. Soc. of America*, Vol. IV, No. 1, Jan., 1920.

THEORY OF REFLECTOMETER.

If light is projected onto the inner wall of a small hollow sphere, painted with a diffusely reflecting white paint, it can be shown that the illumination of the surface by *reflected light only* will be equal in intensity at all points.

Let a small hollow sphere be arranged as shown in Fig. 1. A small segment of the surface is cut away, leaving a hole over

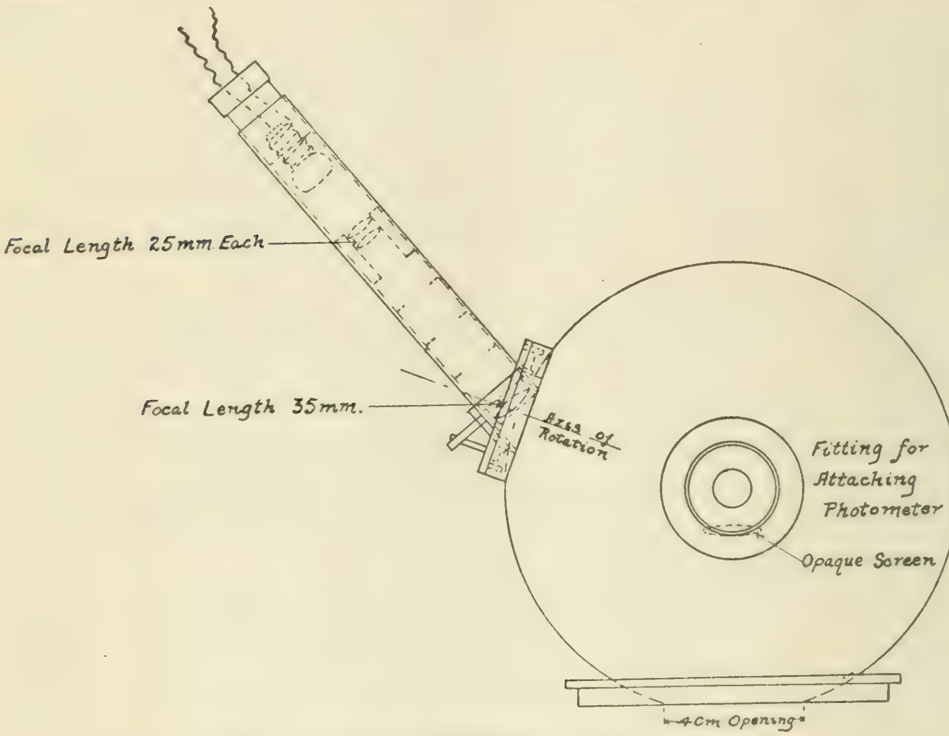

Fig. 1.—Interior arrangement of reflectometer.

which the surface to be tested is placed. At another point on the sphere about 90° from this one there is a small hole through which the opposite wall of the sphere is viewed by means of a portable photometer. The spot viewed is screened from the test surface by means of a small opaque screen.

Let F = total light flux (lumens) entering the sphere.

m = reflection factor of sphere surface.

m′ = reflection factor of test surface.

E′ = illumination of observation point when the direct light is projected onto the test surface.

E = illumination of observation point when direct light is projected onto the sphere surface at a point unscreened from the observation point.

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Fig. 2.—Reflectometer in use.

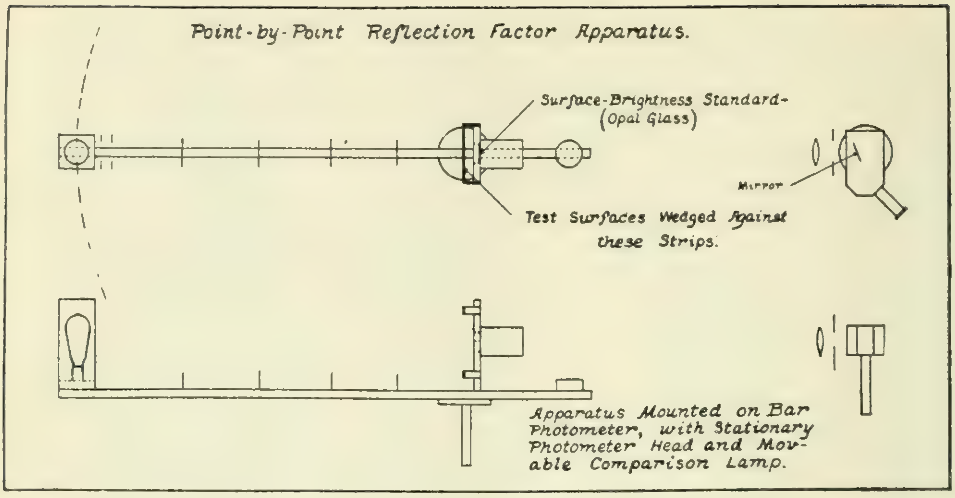

Fig. 3.—Arrangement of apparatus for test.

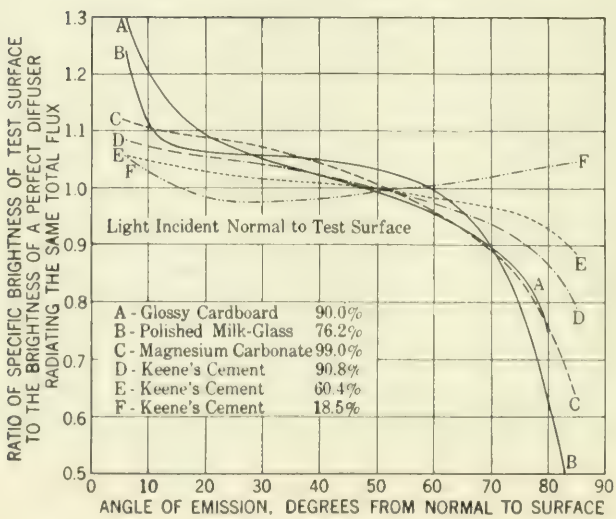

Fig. 4.—Variation of brightness with angle of emission.

When the light is projected onto the test surface, it must be reflected from it and from the sphere walls once each before any of it can reach the observation point, since this spot is screened from the test surface. Hence the flux which is effective in illuminating the spot observed is m′mF. In other words, the flux F, incident on the test surface, produces the same illumination of the observation spot as a point source of light placed at the center of the sphere unscreened from the observation spot, and radiating m′mF lumens. When the incident beam is projected onto the sphere surface at a point unscreened from the spot observed, it is readily seen, by the same method of reasoning, that its effect on the observation spot is the same as that of a point source radiating mF lumens. Hence in each case the illumination of the spot is directly proportional to these flux values, and the numerical value of the ratio of the illumination in the two cases is the reflection factor of the test surface. Or,

$$\frac{E'}{E} = \frac{m'mF}{mF} = m'$$

It is to be noted here that no assumption has been made in regard to the way in which the light flux is reflected from the test surface. Hence the reflection factor of the test surface will be correctly evaluated, no matter how the flux reflected from it is distributed over the sphere wall. Also, the reflection factor measured is the factor for light of the color delivered by the lamp, and is unaffected by selective reflection by the sphere walls.

DETAILS OF CONSTRUCTION.

The details of the instrument constructed are shown in Fig. 1. The lighting tube, which is set at an angle to the sphere surface, can be rotated about an axis normal to the surface of the sphere. This allows the direct light to be thrown on the test surface or the sphere wall as may be desired, the angle of incidence being about 40° from the normal. By means of a good lens system a narrow beam of light, without scattered light, is obtained. This results in a fairly uniform, sharply defined spot of light about 2 cm. in diameter, so that the opening need not be very large. A 2.8 volt opal-back flash light lamp is used in the tube.

The particular instrument used in these tests was designed and built to be used with a Macbeth illuminometer. A lens of 61 mm. focal length inserted in the elbow tube of the illuminometer restricts the spot observed to a diameter of about 4 mm., and hence a very small screen can be used to screen this spot from the test surface.

EXPERIMENTAL WORK.

In order to verify the results obtained with the reflectometer previously described a graded series of test objects was made up. Neutral gray objects were obtained by mixing black drawing ink and lampblack with a white cement (Keene's Fine). They were surfaced with coarse sandpaper, resulting in fairly good diffusers. These surfaces were tested for reflection factors by observation of surface brightness at intervals of 10°, using the apparatus shown in Fig. 3. The amount of flux reflected was calculated from these observations, and since the incident flux was known, the ratio of the reflected to the incident flux gave the reflection factors. These test objects were restandardized and used in verifying the results given by the new reflectometer. To these were added a block of magnesium carbonate previously tested, a polished sheet of milk glass, and a white cardboard painted with the same paint as that used in an 88-inch integrating sphere. The reflection factor of this paint had been previously determined by measuring the total illumination of the sphere wall when a lamp of known candlepower was burned in the sphere.

The tests of the cement surfaces with the first type of reflectometer (described in Scientific Paper No. 391) when used in the way recommended, showed that its results were in almost perfect agreement with those obtained by the point-by-point method.

The results of the measurements with the new type reflectometer described above are shown in Table I.

Such conditions as exist in the following table are probably experimental errors, since the illuminometer is not a high precision instrument. For all practical purposes the two methods may be considered to be in perfect agreement.

In using the instrument no accurate voltage adjustment of the lamps in the photometer and the reflectometer is necessary. as both operate from the same battery. If only approximate factors

TABLE I.—REFLECTION FACTORS BY TWO METHODS OF MEASUREMENT.

Test object	Reflection factor	
	Point-by-point method Per cent.	New type reflectometer Per cent.
Cement Standard No. 1	18.5	19.2
No. 2	38.4	39.2
No. 3	43.2	43.2
No. 4	60.4	60.5
No. 5	67.8	68.1
No. 6	82.3	81.3
No. 7	86.6	86.4
Polished milk-glass	76.2	76.4
Sphere paint	*94.0	93.9
Magnesium carbonate	**99.0	98.5

* Value obtained by measurement of total illumination in 88 in. sphere when a lamp of known candlepower was burned in the sphere.

** Average of all previous measurements by four absolute methods, including the point-by-point method.

are desired, the voltages can be adjusted so that the photometer reads 10 when the light is directed onto the sphere wall, and then the reading when the light is directed onto the test surface is one-tenth of the percentage reflection factor. This eliminates the necessity for any computations.

USE OF INSTRUMENT FOR MEASUREMENT OF TRANSMISSION FACTORS.

By the addition of an exterior light source giving a concentrated beam of the proper intensity, the same instrument may be used to measure transmission factors of clear or diffusing media. In the laboratory such a light source is easily obtained by proper screening of a lamp with a reflector. For precision work the method of procedure would be as follows:

1. Turn the reflectometer lighting tube to project its beam onto the sphere wall at a point unscreened from the photometer observation point, then read the photometer.

2. Place over the opening in the sphere the substance to be tested for transmission, and again read the photometer. Then extinguish the lamp in the lighting tube.

3. Project the beam from the exterior lighting source through the large opening in the sphere, and make a photometer reading.

4. Leaving the exterior lighting source unchanged, place over the opening the substance to be tested, and again read the photometer.

Let the photometer reading (in brightness or illumination units) in the four cases be respectively a, b, c and d. Then the transmission factor of the substance is $\frac{ad}{bc}$.

In using the instrument in this way the exterior light source should produce a beam which is somewhat smaller in diameter than the hole where it enters the sphere, so that when the substance to be tested is in place the light diffused by the substance at the edges of the beam will not escape beyond the edges of the hole.

This method of measuring transmission factors is similar in principle to that employed by Luckiesh and Mellor,[1] but the apparatus and test procedure are different. Transmission factors for diffused illumination might be determined by illuminating the test substance by means of a diffusing hemisphere as in the method used by Luckiesh and Mellor.

CONCLUSION.

Only one adaptation of the principle of this instrument has been shown, but there is no reason why it could not be adapted for use with almost any good type of portable photometer.

There is a considerable advantage in using an absolute instrument of this type rather than an instrument giving relative values, since no standard surface is required and it is not necessary for lamps or sphere surface to remain constant from day to day.

The use of a low voltage flashlight lamp in the lighting tube makes the instrument easily portable and convenient. A further improvement as regards portability would be to eliminate the battery-meter set and substitute therefor a large three-cell flashlight battery, and miniature resistances.

The use of the instrument for measuring both reflection and transmission factors doubles its usefulness. No other instrument having this dual value has been proposed.

[1] Measurement of Transmission Factors, by M. Luckiesh and L. L. Mellor, *Journal of the Franklin Institute*, Vol. CLXXXVI, p. 529, Oct., 1918; also, *Journal of the Optical Society of America*, Vols. II and III, Jan.-Mar., 1918.

This instrument gives further proof of the very high reflection factor of magnesium carbonate, and helps to establish the value of 99 per cent. for a particular block beyond doubt.

DISCUSSION.

This paper was discussed in connection with the preceding paper by Sharp and Little on measurement of reflection factors.

F. A. BENFORD: The two papers have brought out two very excellent points. One of these is that we are apparently agreed within at least 1 per cent. as to what the coefficient of reflection of magnesium is. The other is that one can obtain from any drug store a standard of reflection that is to be depended upon.

LOUIS BELL: The papers show something theoretically of great interest, which is that a high reflection coefficient is given by an easily obtainable substance. In Nutting's determination with the guard-ring instrument, which seems to have presented a possibility of fairly good precision, the results were notably below those obtained by the recent speaker. Can he tell us what the error was that had to be corrected?

How nearly can one actually depend on a surface of magnesium carbonate made up without specification? How shall the surface be prepared to give, say 98 per cent. of reflection? How much does the fineness of grain and amount of compression placed upon it, alter the reflective coefficient? Obviously the fineness of the grain would produce some effect if the surface thus prepared did not conform with the standard conditions.

From a practical standpoint what we want very much is a specification for a standard surface of magnesium carbonate, which one can slip into a Lummer-Brodhun photometer and obtain by comparison, quick and ready measurements of reflection for all types of surfaces. Specifications for making a surface to give specific results at even a moderate range of angles would indeed be very useful.

ENOCH KARRER: With the large amount of work done in the last two years on reflection factors and establishing standards, the Illuminating Engineering Society ought not to be compelled to use surfaces for reflection standards that are in the least doubt-

ful. In this connection I have for some year and a half been attempting to obtain a rather portable reflectometer, one that could be carried by inspectors of the War Department. The small bomb-like reflectometer I show you resembles the Nutting type of instrument. The ring, as Dr. Bell has mentioned, was one of the things that made the Nutting instrument in error. It depended upon the illumination of a surface by an infinite plane, where the density of luminous flux is πb. If a finite surface of uniform brightness b, be made into a hollow sphere, the illumination at any point within the sphere is $\frac{\pi}{a}$ b, where α is the absorption factor of the surface. If a surface with a reflection factor ρ_x is substituted for a small portion of the sphere wall its brightness will be $\frac{\pi}{a}.b.\rho_x$. The brightness of the sphere wall itself is $\frac{\pi}{a}.b.\rho$, where ρ is the reflection factor of the sphere surface.

I use the Martens polarization photometer, as Nutting has done. This photometer is an ideal optical instrument for such purposes, the disadvantages being that it is a difficult piece of apparatus to make and is difficult to obtain at the present time. However, having such an instrument, one can conveniently make such a reflectometer, and can by proper attention to screens inside the sphere, make the reflectometer an absolute one that enables him to determine the reflection factor with one observation.

The hole in the sphere need be only 0.5 sq. in. in area. My method is virtually the same as that used by Dr. Sharp and Mr. Little. At the same time, it can very easily be seen that instead of moving the photometer, the test can be made so that one can look at two surfaces at the same time, and thus read off the reflection factors immediately.

In order to make a reading of the reflection factor of the substance with one setting a scale must be attached to the photometer scale which is originally graduated in degrees. For ordinary, practical purposes, it is easy to get some kind of a reflectometer to measure the relative factors, but for an absolute reflectometer, such as Mr. Taylor has described, it is not so easy to get one as portable and as cheap perhaps as illuminating engineers might desire. For practical purposes I should say that an instrument giving relative values would be satisfactory because real durable

surfaces can be secured and calibrated once for all. So I have devised a little instrument which I had hoped to use in this connection. It is not perfect optically; it is merely a suggestion. In this case there has been substituted for the Martens photometer, a small Lummer-Brodhun head.

I have measured the reflector factors of surfaces with the assistance of Mr. Taylor, he having supplied for this purpose his standard surfaces. A few of the measurements which I have made indicate that the first instrument gives correct reflection factors to within the errors of measurement. The reflection of the magnesium carbonate is an important subject. Physicists have made the same error as the Illuminating Engineers in this respect by assuming the reflection factor of magnesium carbonate to be as determined by Nutting. It is as important to physicists to know the reflection of magnesium carbonate as it is to the illuminating engineer. The reflecting factor of a block of carbonate measured with this instrument proved to be 98.7. That is the highest value I have found for magnesium carbonate, but Mr. Taylor has values somewhat higher. The lower value given by my instrument is probably due to the crudeness of it. I have not spent any time in making it optically perfect.

One cannot expect to buy from a drug store carbonate blocks or any other standard physical apparatus. It would be an admirable thing for the Illuminating Engineering Society to encourage some standard scientific instrument makers to furnish for such technical use magnesium carbonate of guaranteed purity and texture. The block I have is kept in a closed box, because it will vary either by exposure to the atmosphere or dust. A block must occasionally be scraped and then a person is not exactly justified, I should say, in assuming that it is uniform throughout its whole depth.

In using the magnesium smoked surfaces as physicists have done from time to time, care must be taken as to the quantity of smoke on that surface, in order to have the same reflection factor as a magnesium carbonate block.

C. H. Sharp: How do you get the light?

Enoch Karrer: In this case the light comes from a small flashlight lamp which is crudely mounted without any lens. The

Martens photometer is very inefficient. A lens ought to be added to concentrate the beam.

It may be also that the reflection factor with sunlight is desirable. To make this possible, I have so mounted a mirror as to be free to turn on two axes so that the sunlight can be thrown into the sphere. The lamp, of course, is removed before the mirror is mounted. The batteries for the lamp are mounted in the two handles.

E. W. COMMERY: Mr. Taylor has placed particular emphasis on the portability of the reflectometer which he describes. In this instrument use is made of two lamps which would suggest the necessity of employing an electrical measuring device to set the proper value of current and also to keep a check on any drift which might occur with either of the lamps. I would like to ask Mr. Taylor what method he employs to eliminate the use of an electrical measuring device for keeping this check.

In connection with this discussion of a number of interesting instruments which have been developed for the determination of reflection factors, mention should be made of a portable type developed by Mr. R. N. Falge of the Engineering Department of the National Lamp Works about a year and a half ago. The instrument is based on the principles of the integrating sphere with the auxiliary photometric devices greatly simplified. As the integrator use is made of a box with one of the sides removed, this side being closed by the sample to be tested. The direct light from a lamp located in the opposite wall to this opening is allowed to fall on the surface to be tested which in turn reflects the light on the adjacent and opposite walls. The first reflection is prevented from falling on a row of grease spots, such as is used in the foot-candle meter scale, by a screen. The multiple reflected light illuminates these spots in proportion to the reflection factor of the sample tested. To the observer these spots appear illuminated by transmission. To secure a balance at any given spot it is necessary then merely to vary the light on the observer's side of the scale, which is accomplished by means of a variable opening in a cylinder, surrounding the same lamp that illuminates the test sample. The calibration of this variable opening in turn is accomplished by reading a number of known samples with the

instrument. Using only one lamp, the rheostats, electrical measuring devices and constant-potential sources are eliminated. The complete apparatus was made up in a form measuring about 3x5x2 in., and giving results accurate to within about one point.

A. G. WORTHING: The instrument which Dr. Sharp and Mr Little have developed is a very interesting one. We regret particularly the assumption that the surface within the sphere is perfectly diffusing, for no surface is perfectly diffusing. What, therefore, is the possibility of error resulting from the lack of perfect diffusion? Taking the case of magnesium carbonate, Dr. Forsythe recently showed me the curve representing its deviation from perfect diffusion; at 45° from normal, the brightness of such a surface appears to be about 7 or 8 per cent. less than when it is viewed normally. This is appreciable.

If a sphere could be so painted as to reflect the light so that it came back and fell entirely upon the opposite half of the sphere; that is, if the beam of light that came from the spot that Sharp and Little used, covered only the opposite half of the sphere, not illuminating the unscreened spot sighted on for obtaining B in their formula $r = \frac{B_s}{B}$, and an absolute determination of the reflection factor of the wall paint were attempted in the prescribed manner, then, whatever the reflection factor, 100 per cent. would be obtained as the measured value.

Of course, we probably have no such paint and wouldn't use that kind of paint in a sphere anyway, but the necessity of watching for the lack of uniformity in the diffusion is apparent. Messrs. Sharp and Little, fortunately or otherwise, chose a position for their test spot which was 90° away from the source, the light spot, and perhaps through that choice they averaged out errors resulting from the failure of magnesium carbonate, or of the paint used, to reflect perfectly diffusely.

It would be easy to show that, if they had chosen the test spot close up to the light spot, there might be quite an error. Whether the actual choice was a matter of accident or whether it was intentional, I don't know, but I think it was fortunate.

DAVIS H. TUCK: Mr. Taylor's instrument will be used by illuminating engineers to measure the reflection coefficient of actual walls and ceilings. In measuring the reflection coefficient in this room, it would be easy to measure the coefficients of the walls, but that of the ceiling would be hard to measure. In its final form, I hope the arrangement will be such that one will not have to stand on his head to measure the reflection coefficients of ceilings.

C. H. SHARP: Dr. Bell asked a question about the error in Nutting's instrument. I think Mr. Benford who has analyzed that, can answer the question better than I can.

As to the preparation of magnesium carbonate, he has suggested a very interesting field for further research.

Mr. Karrer's instrument is very interesting indeed. We are all glad to see further developments, and I think he has made a material contribution to the art.

I want to congratulate Mr. Taylor on reducing his theory to very practical form, giving us an instrument which can be used in the field. I wish to ask him regarding the crossing of his lines at 50°, whether that isn't conditioned upon the illumination on the substance being a perfectly diffused illumination, and further to ask whether there may not be some one direction from which light may be thrown upon a test surface, where the same thing would be true.

If such a direction could be found, we would have a principle for constructing a very simple reflectometer for approximate work without the use of a sphere.

Dr. Worthing suggested that the accuracy of the results which are given in our paper was due to a happy accident in choosing the position and arrangement of parts of the apparatus. Of course, that wasn't quite an accident. We really did think about it somewhat, and the arrangement described represents the results of our best judgment in the matter. I want now to call attention to some things in the paper which evidently have been overlooked.

This method we have shown is an absolute method. It doesn't depend upon any standards. Not only that, but it lends itself to a check of a very convincing character, that is, as a test sample, we can use a plane glass mirror calibrated independently on a

photometer bar. We have done that and have obtained a reasonably good agreement between the value found on the bar and the absolute determination by means of the sphere.

It stands to reason, if a method gives a correct answer for a plane glass mirror and for a substance which is a fairly perfect diffuser, it will hold also for reflectors of intermediate character just as the theory shows that it must do.

About magnesium carbonate, it appears quite evident that this substance, as one buys it in drug stores, isn't an entirely satisfactory standard of reflectivity, although it is remarkably good, everything considered. However, there have been recorded a great many measurements in the Society's TRANSACTIONS and elsewhere, relative measurements which have been made against magnesium carbonate block as a standard, assuming the erroneous value of 0.88 as the reflection factor of the magnesium block. These data must be converted to correspond with our present knowledge of the reflection factor of the standard and for this purpose a standard value for the reflection factor of magnesium carbonate block is desirable.

Mr. Taylor has been fortunate in getting a number of blocks of exceptionally high reflection value. In Mr. Benford's paper, the values are not presented as being so high. We found values running between a little over 100 per cent. down to 96 per cent. This range is due to errors of observation plus the differences between blocks. Taking everything into consideration, it would seem reasonable to suppose that the magnesium carbonate blocks which have been used in the past as standards, with the assumed value of 88 per cent. probably had somewhere around 98 per cent. reflection factor.

The suggestion is made in this paper that when we correct the old data based on 88 per cent. for magnesium carbonate, we assume a standard value of 98 per cent. which represents apparently a pretty good average of the different carbonate blocks, and is a good round number to fix upon for this purpose.

Of course, in the future, in any precision work, there will be no excuse to assume the value of magnesium carbonate or anything else. One can use a sphere and ascertain the absolute values. If a Marten's polarization photometer is used, the result can be obtained from one setting. That eliminates a little of the labor,

but not much, because it is nearly as easy to take two readings as one unless a great deal of this work is being done.

A. H. TAYLOR: It is quite interesting to note that after having accepted Dr. Nutting's value of 88 per cent. for the reflection of magnesium carbonate for eight or ten years, we find out it is wrong. Thus the subject has been reopened and several types of reflectometers have been developed.

The question was asked as to the errors in the Nutting reflectometer. In Scientific Paper No. 391 of the Bureau of Standards, I pointed out some of the possible errors, and I will just review those. First of all, the instrument is based on the principle of parallel infinite planes. The planes as actually used in the instrument are quite limited in area, being about 5 or 6 in. in diameter, and for a portion of the so-called infinite luminous plane there is substituted a nickeled ring. This ring would have to have a 100 per cent. reflection factor in order to take the place of the infinite plane there. The polarization photometer must be inserted through the ring, thus disturbing the distribution of light upon the two planes. It will decrease the illumination of the secondary plane. Tests relating to the lack of perfect diffusion of various surfaces, show that we don't really know what does happen when there is diffused illumination of a surface viewed at 75° from the normal. Hence there are three very fertile sources of error, and it is hard to know which contributes most to the total. Probably they will all add up to make the determination incorrect.

It is a source of gratification to me to know that Dr. Sharp's and Mr. Little's instrument checked the value of a milk glass plate which I standardized for them at the Bureau of Standards. This result shows that our instruments are in agreement, and is further verification of the very high reflection factor which I observed for a particular block of magnesium carbonate.

As to the drift in the voltage of the lamps, it is to be noted that I do not read the milliammeter at all. What I do is to take five readings, say, with the light incident on the test surface, then turn the lighting tube to project the light onto the sphere surface and take ten readings, then take five more with the first condition. That method will compensate for any drift in the lamps. It is the procedure I followed in obtaining the experimental data reported in the present paper.

In preparing recently a paper on the theory of the sphere, I attempted to find out what portion of the total illumination of any spot on the wall is contributed by the first reflection of the incident flux. I find that there is a very simple relation and that this portion is simply the absorption factor of the sphere surface. For instance, with 90 per cent. reflection factor (assuming this spot is screened from the test lamp) the spot observed receives 10 per cent. of its total illumination from this first reflection. Since the largest part of any error due to imperfect diffusion is caused by improper weighting of the first reflected flux, this error evidently would not be very large in most cases.

I have tested a large number of surfaces for surface brightness in preparing the standards for checking these instruments. I suppose I have measured twenty-five or thirty different surfaces, among which were magnesium carbonate surfaced with a sharp glass edge, glossy milk glass, filter paper and various surfaces like that. In each case the surface brightness at the various angles was measured when the surface was illuminated normally. Of all surfaces photometered I find that glossy milk glass is the one which deviates most from the brightness of the perfect diffuser at 50°. Most of the rest of them are within 1 per cent. I don't just see why that should be, but it is true, anyway.

There are only three requirements for the instrument which I have just described: First, all of the direct light shall be incident on the test surface when the tube is turned down; second, the test surface should be screened from the observation point; and third, the sphere surface should be uniform.

In regard to the portability of the instrument, I have not by any means exhausted the possibilities. In the present paper I pointed out one method of improving it. By the addition of a mirror to the photometric system, one need not "stand on his head" to measure the reflection factor of a ceiling.

W. F. Little: The question of the position of the spot of light upon the sphere surface has been referred to. Several experiments were made with the spot projected at different locations in the sphere and it was found that no measurable difference could be detected provided the spot was small and properly shielded from the test surface. In one set of measurements the spot of

light was projected 1.5 in. to one side of the test surface and the screen was only 1 in. long and ⅛ in. high and so placed that a minimum of light and sphere surface was intercepted. In spite of Dr. Worthing's statements, the results so obtained were quite in accord with values obtained as here reported. This arrangement would have been maintained throughout had not the projector been uncomfortably close to the head of the operator.

A very successful portable reflection factor meter has been in use at the Electrical Testing Laboratories for the past year and a half. Its one disadvantage is its size. If one inadvertently slip it into his pocket, he may lose considerable time in finding it. It requires no meter, no batteries, no standards. It is a small photographic wedge made in the form of a 2-in. disc with a series of holes punched near the periphery. The wedge varies in reflection factor from about 0.08 to 0.80. The setting is made by placing the disc over the test surface and comparing the two surfaces in a similar manner to the reading of a foot-candle meter. Its accuracy bears the same relation to a real reflection-factor meter just described, as the foot-candle meter bears to a real photometer. On the whole, it is quite good enough for commercial work.

C. H. SHARP: May I repeat my question to Mr. Taylor? His curves (Fig. 4) show that 50° is the appointed angle. Everything crosses when you have diffuse illumination.

A. H. TAYLOR: The light was incident normal to the surface.

C. H. SHARP: Then, if that is the case, by throwing light normally on the surface and viewing at 50°, one can determine the reflection factor of any surface without any further to do?

A. H. TAYLOR: I think one could determine the reflection factor with such measurements as I have described. I thought of adopting that principle in somewhat the same way that is used in the calibrating device for the Macbeth photometer. To do this it would be necessary so to arrange the device that surfaces illuminated normally would be viewed at 50°. I did not have time to do this, however.

SOME APPLICATIONS OF THE PHOTOELECTRIC CELL TO PRACTICAL PHOTOMETRY.*

BY W. E. STORY, JR.

I. LAMP PHOTOMETRY.

The use of a photoelectric cell has often been suggested for the measuring of light. Up to the present, however, the use of this apparatus has been confined entirely to laboratory experiments. Certain characteristics of the cell that would render it unfit for some purposes seem to have prevented its application to any great extent even in the field in which it offers obvious advantages over the ordinary photometer.

In measuring the candle power of incandescent lamps in factories for example, almost invariably is each lamp compared with a standard of similar design run at about the same efficiency. In other words the measurement is of small differences from a standard of illumination of approximately the same color. To this work the photoelectric cell seems capable of easy adaptation.

Perhaps the simplest arrangement is shown in Fig. 1.

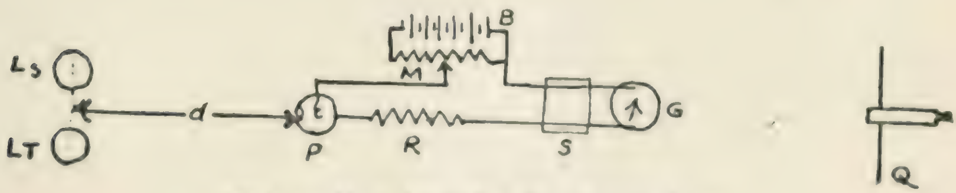

Fig. 1.—Use of cell for direct comparison.

Here the standard lamp (L_S) and test lamp (L_T) are placed in front of the cell (P) symetrically with respect to it. With neither lamp lighted the galvanometer scale (Q) is set to zero. The standard lamp is then lighted and the cell distance (d) adjusted until the scale deflection is 100. When this light is put out and the test lamp lighted, the percentage of its illumination as compared to the standard can be read off directly from the scale, since the deflection from a properly made cell has been

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found to be proportional to the light falling upon it within certain limits of illumination. If it is inconvenient to change the distance (d), the deflection due to the standard lamp can be set at 100 by change of the cell potential by means of the potentiometer (M).

This method, of course, involves the use of a highly sensitive galvanometer, and is not adapted to a portable outfit. If the switchover from one lamp to the other is made very quickly, and a damping shunt (S) is put in the galvanometer line, there is but little time lost in waiting for the galvanometer to come to rest. A screen cutting off either or both lamps can of course be used instead of the switch-over.

Another limiting feature of the method is that since the standard and test lamps are run at different times, the potential lighting them must be constant from one time to another. This practically necessitates a storage battery.

Data of runs made with this method are given in Table V. The galvanometer used had a resistance of 550 ohms and a sensitivity of 7.8×10^{-10} amps.

It might be noted that if it is desired to measure the mean spherical candlepower the cell may be hung inside a photometer sphere with the lamps as long as the light does not shine directly into the cell.

For factory testing it would be desirable to eliminate the storage battery. Accordingly the standard and the test lamps were run together off the same line and each illuminated a separate photoelectric cell. These cells formed two arms of a Wheatstone bridge as has been tried a number of times before. The connections are shown in Fig. 2.

The standard lamp (L_1) is set at 100 on the scale (S_1) graduated according to the square of the distance from (P_1). A secondary standard (L_2) is put in the other sliding socket and its distance adjusted to balance the standard. The lamp to be tested is then substituted for the standard and the distance on the (S_1) scale adjusted to balance the secondary standard. The candlepower of the test lamp in per cent. of the standard is read off on the scale. It will be noticed that if the secondary standard is of the same type as the lamps to be tested, small changes of potential will not materially effect the comparison.

TABLE I.

Galvanometer Step	Cell volts	Deflection Standard	Deflection Test	Per cent.
		15 Watt vacuum lamps at 125 volts		
		d = 17¾″		
1.0	66	2.29	2.08	90.9
		2.29	2.07	90.4
		2.30	2.09	90.8
		2.30	2.09	90.8
1.0	132	4.4	4.0	90.8
		4.4	4.0	90.8
		4.4	4.0	90.8
		4.4	4.0	90.8
1.0	260	16.85	15.26	90.6
		16.85	15.25	90.6
		16.85	15.25	90.6
		16.83	15.23	90.5
0.1	310	4.8	4.33	90.3
		4.8	4.34	90.5
		4.8	4.32	90.0
		4.8	4.32	90.0
		60 Watt carbon lamps at 115 volts		
		d = 17¾″		
1.0	66	3.69	3.42	92.7
		3.69	3.42	92.7
		3.68	3.41	92.7
		3.67	3.41	92.9
1.0	132	6.90	6.42	93.0
		6.90	6.42	93.0
		6.90	6.43	93.2
		6.90	6.43	93.2
1.0	260	26.32	24.34	92.6
		26.32	24.33	92.5
		26.33	24.34	92.5
		26.32	24.35	92.7
0.1	310	7.37	6.85	92.9
		7.39	6.85	92.7
		7.37	6.84	92.8
		7.37	6.85	92.9
		200 Watt gas-filled lamps at 125 volts		
		d = 52¼″		
1.0	65	10.0	8.38	83.8
		10.2	8.40	84.0
		10.2	8.40	84.0
		10.2	8.40	84.0
1.0	130	19.0	15.88	83.5
		19.0	15.89	83.7
		19.0	15.9	83.7
		19.0	15.9	83.7
0.1	256	6.72	5.64	84.0
		6.72	5.63	83.8
		6.72	5.63	83.8
		6.72	5.62	83.7
0.1	305	14.72	12.40	84.2
		14.72	12.33	84.3
		14.63	12.32	84.3
		14.60	12.30	84.3

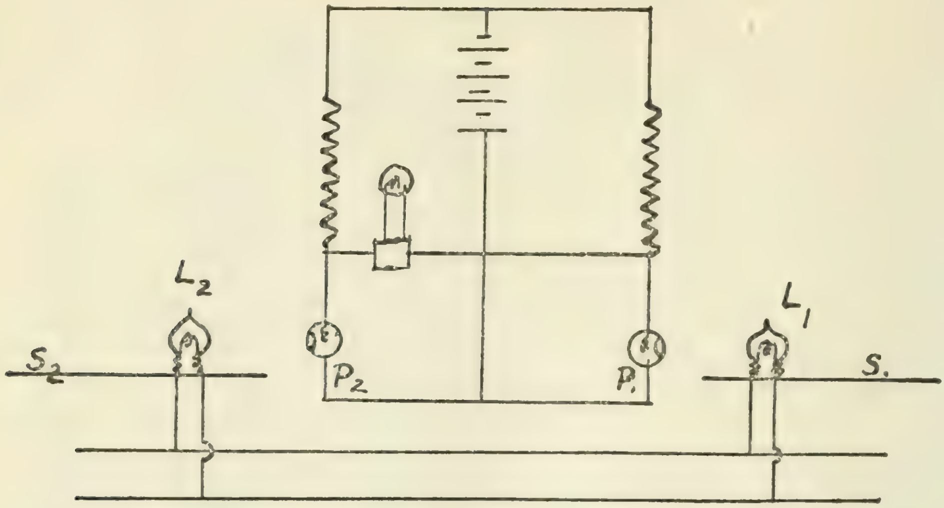

Fig. 2.—Wheatstone bridge method of connecting the cells.

The accuracy of this method depends on the constancy of the ratio of the sensitivities of the two cells during the test. This can be materially improved by combining the two cells in one double cell having a metallic partition dividing the space into two equal chambers as indicated in Fig. 3.

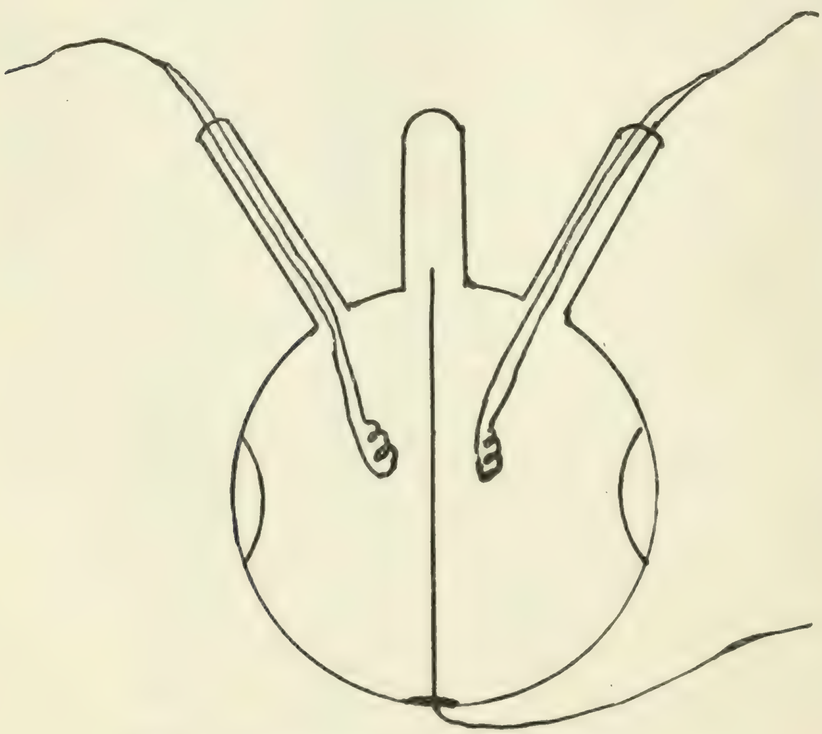

Fig. 3.—Arrangement of a double photoelectric cell.

No effort is made to prevent the gas from circulating freely between the two chambers—the partition serving only to confine the electrons set free by the light through either window to the anode on that side of the partition. In this way any variation due to changes of the gas and temperature are equalized in the two sides. If approximately the same amount of light is allowed to fall on both windows at all times, (*i. e.*, both lamps are turned off and on together) this cell will give a means of comparing lamps in this way quite accurately even without a very constant source of potential.

In Tables II and III are given comparisons obtained by this method. All three lamps used were of the 200-watt, 125-volt, gas-filled type. The 125-volt line had a fluctuation of ±½ volt. The cell potential was 67 volts. No inverse square scale being at hand, the readings are all given in centimeters from the cell window.

TABLE II.

Standard (set at)	Secondary standard (to balance std.)	Test lamp (to balance sec. std.)	Maximum variation
54.5	59.20	52.7	
	59.22	52.82	
	59.5	52.85	
	59.3	52.85	
		52.79	
Average	59.3	52.8	.15 = .3%
54.5	59.25	52.8	
	59.25	52.75	
	59.02	52.8	
	59.1	52.75	
		52.78	
Average	59.15	52.78	.05 = .1%

A comparison of the standard lamp with the secondary standard was made with different cell potentials. The results are given in Table III. In each case the standard was set, and then ten settings of the secondary standard made to balance. The ten readings of each set always agreed to within ½ per cent., so the average alone is given here.

TABLE III.

No.	Cell Volts	Standard (set at)	Secondary standard (To balance. Average)
1	67	5.45	58.64
2	132		58.71
3	262		60.59
4	310		60.80
5	67		58.93
6	132		59.16
7	262		61.47
8	310		61.65

These figures indicate a change in the ratio of the sensitivities of the two sides of the cell with a change of cell potential. Furthermore, the ratio of sensitivities does not necessarily return to its former value with return of the potential. This change does not affect the accuracy of the comparison, of course, but simply indicates that a reset of the secondary standard must be made for any material change of the cell potential.

It was found that a change of ½ per cent. in the distance of the secondard standard (*i. e.*, 1 per cent. in the illumination of its window) gave approximately 1 millimeter deflection. With the above lamps a change of 8 volts in the line was necessary to produce a deflection of 1 millimeter after the lamps had been balanced at 125 volts. Accordingly, if we require an accuracy within 1 per cent., we can use a line having fluctuations of at least 8 volts for testing these lamps. If an accuracy with 2 per cent. is sufficient, then the line may have fluctuations of at least 24 volts.

For a portable set it is undesirable to use a suspension galvanometer and resort must be made to amplification. The connections are shown in Fig. 4.

Between the cell (P) and the resistance (R_1) is connected the grid of a pliotron (N). By means of the battery (B_5) and the potentiometer (M) the plate current for zero light in the cell is balanced to give a zero reading on the microammeter (A). The reading is then adjusted to 100 for the standard lamp (L_S) by means of resistance (R_3) and then other lamps (L_T) are measured directly in percentage of this standard.

In order to have a deflection proportional to the light, the characteristic curve of the pliotron must be a straight line through the range considered. A battery (B_2) serves to shift this straight part to this range. Any variation from the straight line characteristic for deflections from zero to the maximum will introduce

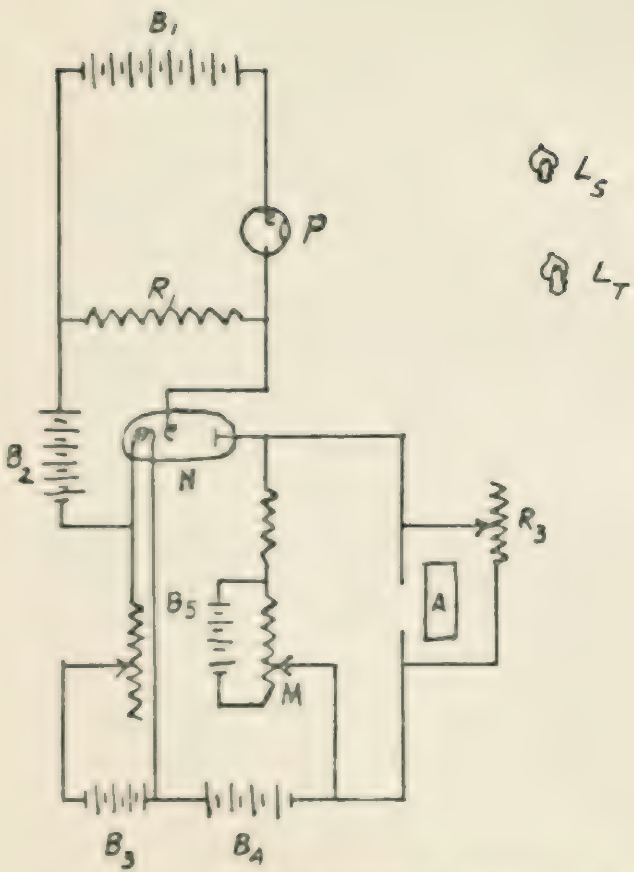

Fig. 4.—Connections of portable set.

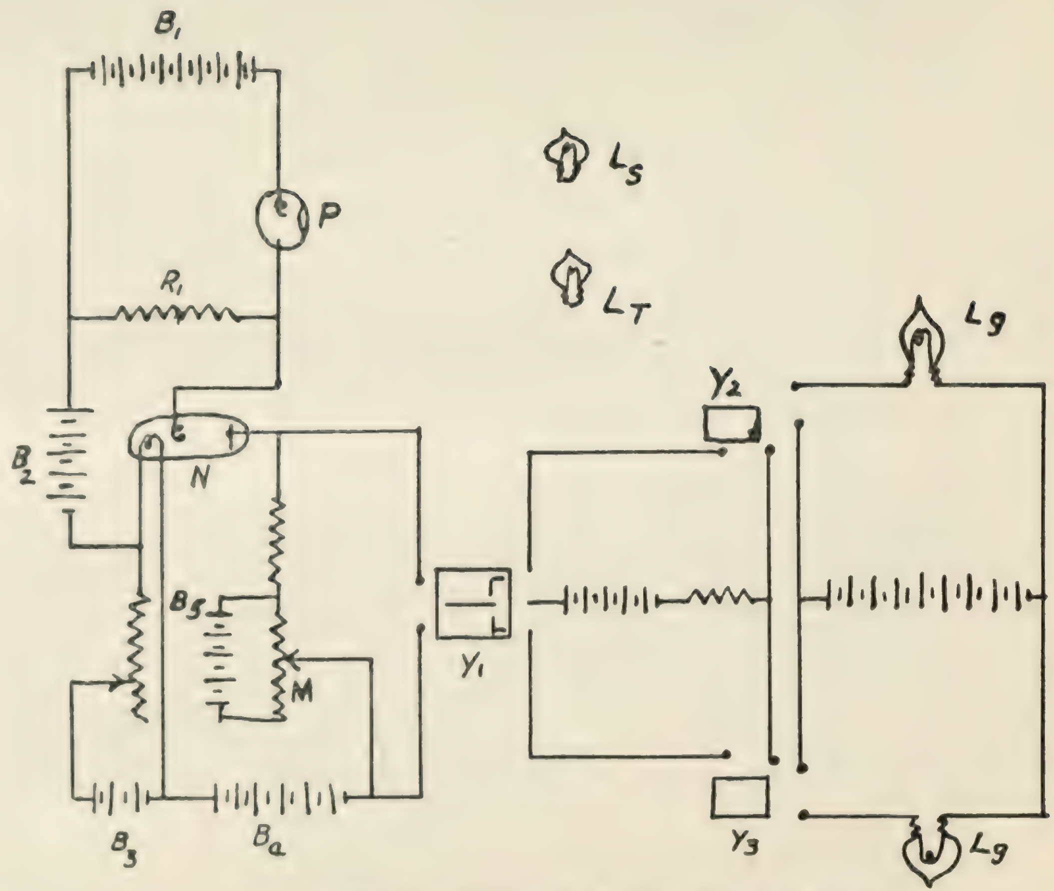

Fig. 5.—Connections for rapid sorting of lamps.

inaccuracies in the results unless the apparatus is calibrated and the proper correction applied.

This method has the disadvantage spoken of above of requiring a constant source of potential for the lamp to be tested if accurate results are demanded.

Another arrangement (Fig. 5) of the same type can be used satisfactorily for rough but very rapid sorting of lamps for candle-power. For the microammeter is substituted a highly sensitive relay (Y_1) operating two other heavier relays (Y_2 and Y_3) for lighting signal lamps (L_g) or closing other circuits for the automatic sorting of lamps in factories. In this case the potentiometer (M) is adjusted so that standard illumination gives a neutral position of the sensitive relay.

With this arrangement it is easy to adjust sufficiently accurately to light a signal for variations of 1½ volts either way when testing a 125 volt lamp.

A two stage amplification is being now tried to increase this sensitivity.

II. MEASUREMENT OF THE TOTAL QUANTITY OF LIGHT IN A PROJECTED BEAM.[1]

Initial efforts to measure with a Sharp-Millar photometer the quantity of light emerging from the objective of a motion picture machine for various positions of the condensing lens, proved such a laborious process that a search was made for some means of recording automatically the quantity of light at each instant, as the position of the condenser was continuously changed. A schematic representation of the present arrangement is given in Fig. 6.

The source (S) usually employed was a piece of opal glass lighted from behind by a 500 watt stereopticon lamp. In front of this opal, there was slipped a thin sheet of brass pierced by a square hole: the size of this hole determines the size of the light source. The condenser (C) concentrates the light on the aperture (A). Instead of an objective beyond this aperture, as in the ordinary arrangement, a circular hole (D) in a brass plate at a distance (d_3) from the aperature allowed passage to all of the light which would normally fall upon an objective, the effec-

[1] Part II of this paper is a modified abstract of an article appearing in the Transactions of the Society of Motion Picture Engineers of May, 1920.

tive diameter of which was the diameter of the hole, and the equivalent focus of which was d_3. Due to the different forms of objectives in use, with their different efficiencies, it was decided to determine the quantity of light delivered to the objective as a first step and then to take up the changes of efficiency with the size and type of objective as a separate problem. The first of these is the only one considered in the present paper.

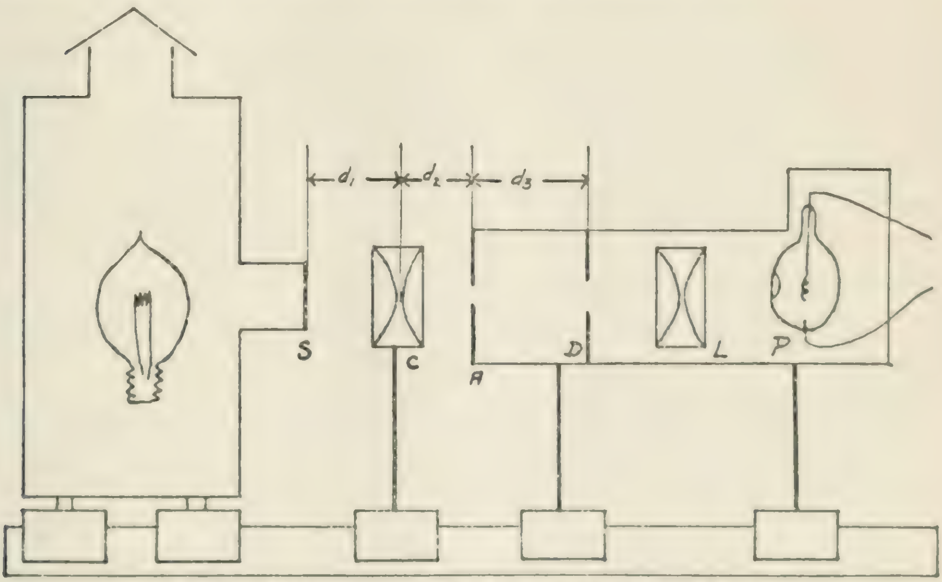

Fig. 6.—Measurement of light from a projected beam.

Beyond the dummy objective (D) then, a secondary condenser (L) large enough to cover the largest objective to be used, threw an image of the aperture on the window of the cell (P). This means that a constant proportion, determined by the reflection and absorption of this condenser, of all the light from the aperture that would fall on the objective, enters the cell. As long as this condition is fulfilled, of course, the actual distance of this secondary condenser from the objective opening and of the cell from this condenser is immaterial.

The various parts of the apparatus were mounted on an optical bar—the condenser (C) being in a fixed position and the rest moveable. The source could be moved about by hand to obtain any distance d_1 required. d_2 was changed by a motor-driven worm gear, moving A, D, L and P as one assembly along the bar. The dummy objective could be set by hand at the selected distance from the aperture. Accordingly for any given size and

brilliancy of light source, any d_1, any condenser and any size and focal length of objective, the quantity of light entering the cell will change with changes of d_2. To plot this curve the following arrangement was employed.

To the supports of the aperture-cell assembly, a cable was fastened which, running over pulleys, determined the height of a photographic plate sliding vertically in a light-tight box. In the side of this box close against which the plate ran there was cut a narrow horizontal slit, protected when desired by an opaque shutter. An open lamp was flashed in front of this slit whenever the pointer attached to the sliding assembly crossed one of the inch marks on the optical bar scale. Since these marks measured inches from the reference plane of the condenser, the plate was thus marked with a series of equispaced horizontal lines corresponding to the integer values of d_2. In the present work the actual motion of the plate was reduced by a pulley to one-half that of the aperture-cell assembly.

The electrical connections consisted simply of a battery of dry cells and the photoelectric cell in series with the shunt of a 550 ohm galvanometer (sensitivity 2.93×10^{-10} amp.).

The mirror of the galvanometer reflected the light from a vertical incandescent filament to a vertical image on the slit in the plate box. As the galvanometer needle turned then, this image travelled across the plate registering by its horizontal distance from its zero position the current flowing through the galvanometer and so the light entering the cell.

Accordingly when the plate is exposed behind the slit, we have a series of horizontal lines marking the inch values of d_2, and a curve showing the change of light with change of d_2. For the sake of convenience the d_2 axis is taken as the axis of abscissae and the deflection axis as the axis of ordinates.

To determine how nearly the deflection was proportional to the light delivered to the objective, the condenser (C) and the opal glass (S) were removed and an opal glass put over the aperture (A). The brilliancy to which this opal is illuminated will be, of course, inversely proportional to the square of its distance from the source lamp, and since the light entering the cell is proportional to this brilliancy, if the light entering the objective

can be measured directly by the deflection, it should be proportional to the inverse square of the source—aperture distance.

This proved to be the case well within the limits of accuracy of the experiments. Also the ratio of deflections with two sizes of objective was within narrow limits calculated from their diameter (loc. cit.). It might be added, however, that this condition of proportionality obtained with only two of the cells so far made.

A sample plate indicating the total light in a projected beam is shown in Fig. 7.

This plate is made with a plano convex condenser and a square light source ½″ on a side. The upper family of curves represents the light delivered to a 2½″ objective and the lower to a 1¾″ objective—both of 5½″ equivalent focus. Each family is made up of curves differing from each other in the value of d_1.

It is evident that if we leave out the condenser and use a source of uniform brilliancy sufficiently large to back up the entire aperture as seen from every part of the objective, we shall get an illumination that can never be exceeded by any arrangement of condensers or reflectors as long as our source brilliancy and objective diameter and distance, are unchanged. Accordingly the condenser was removed, the source increased to 2″ and, using the 2½″ dummy objective, the distance from the aperture plate to the source decreased from a large value. At first the curve follows the inverse square law, but as d_2 decreases there comes a time when the size of the source is sufficient to cover the aperture from every point of the objective and for values of d_2 smaller than this, we should expect constant illumination. The plates have not shown a perfectly flat top to this curve because up to the present a uniform illumination has not been obtained nor is the opal glass a perfect diffuser. Experiments are now under way to correct this defect. Up to the present the ordinate of this curve at a source—aperture distance of 1½″, which represents perhaps an average value of source brilliancy, has been chosen as unity and all other ordinates measured in terms of this as indicated. In Fig. 7 the curve to determine maximum possible illumination with the 1¾″ objective is shown instead of the 2½″. From other plates the smaller objective was known to give 51 per cent. of the light the larger one gave, though subtending only 49.3 per cent. of the angle at the center of the aperture. Repeated checks on this

value lead to the conclusion that the difference is due to lack of perfect diffusion on the part of the opal glass. The probable inaccuracy here does not effect the comparison of one curve with another.

Fig. 7 illustrates the ease of this method of picking out the precise value of each distance necessary to give maximum illumination.

There are a number of things of minor interest shown in Fig. 7, to which it might be worth while to call attention.

When $d_1 = 3.7''$—which is the focal length of the central portion of the condenser—the deflection is a constant for small values of d_2. This is because for this d_1 the rays from the center of the source, falling on different points of the condenser, leave it parallel to its axis, and rays from other parts of the source to each point, form cones about these lines as axes (Fig. 11a). These cones all having approximately the same vertex angle, will illuminate a small area on the axis of the condenser, such as the aperture, with the same amount of light irrespective of the distance from the condenser, as long as this distance is not large enough for the aperture to cut into the outer cones. For values of d_2 larger than this a lens without aberrations would show a gradual falling off in intensity. The rise in the curve $d_1 = 3\frac{3}{4}''$ (Fig. 7) is due largely to the spherical aberration of the condenser used.

Since the smallest objective ($1\frac{3}{4}''$) is considerably larger than the aperture, if the beam coming through the aperture diverges but slowly, the quantity of light falling on the objective is independent of its area.

Accordingly if d_2 is large with respect to the condenser the $2\frac{1}{2}''$ and $1\frac{3}{4}''$ objective families should coincide. This tendency the curves of Fig. 7 show.

Again if d_2 is so small that only the nearly parallel rays emerging from the center of the condenser pass through the aperture, the families will coincide. This is shown plainly.

It is interesting to note that all the curves for both $2\frac{1}{2}''$ and $1\frac{3}{4}''$ objectives pass through a common point, namely: $d_2 = 3.7$, deflection $= .11$.

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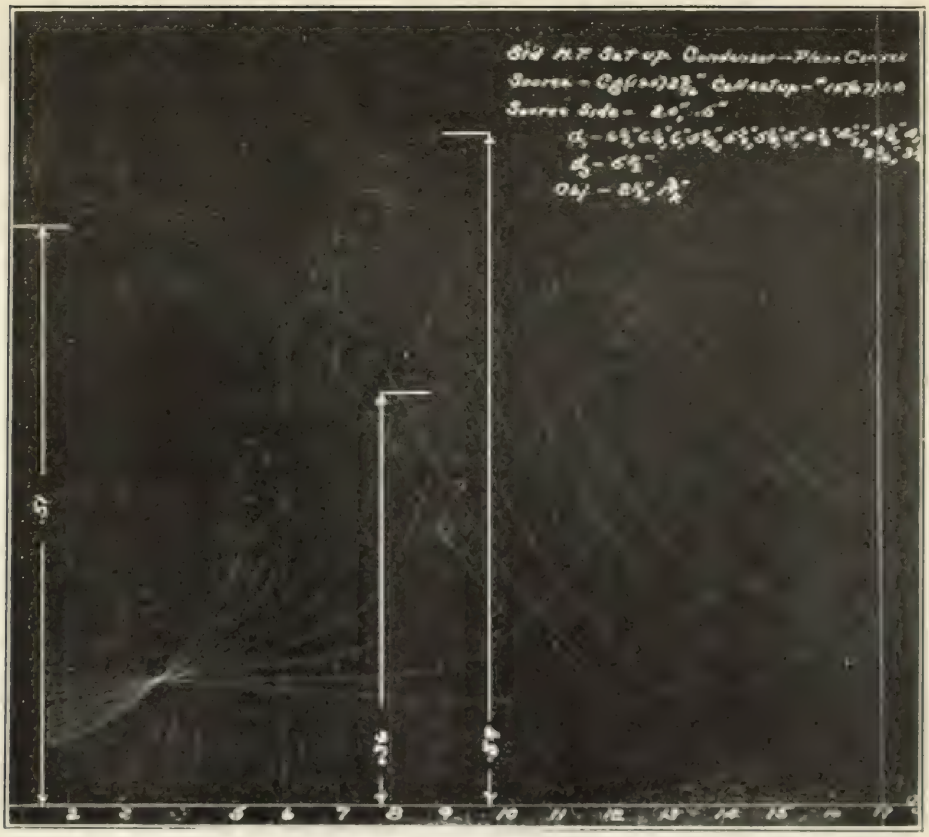

Fig. 7. Total light in a projected beam.

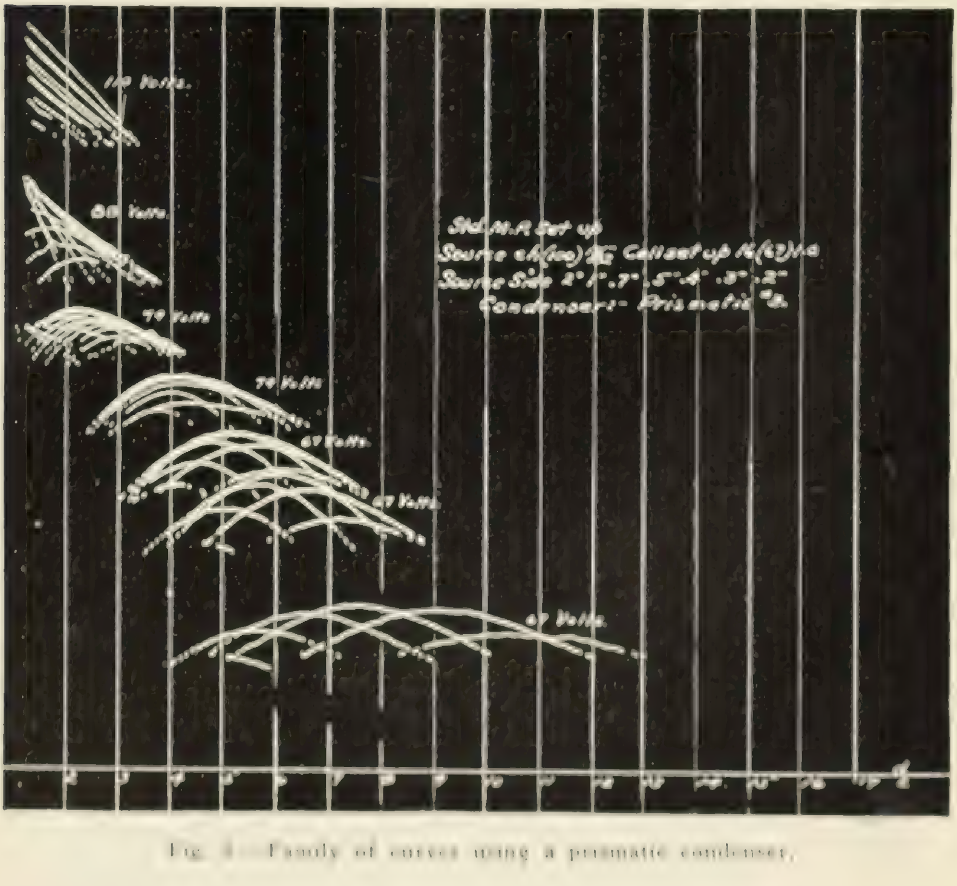

Fig. 8. Family of curves using a prismatic condenser.

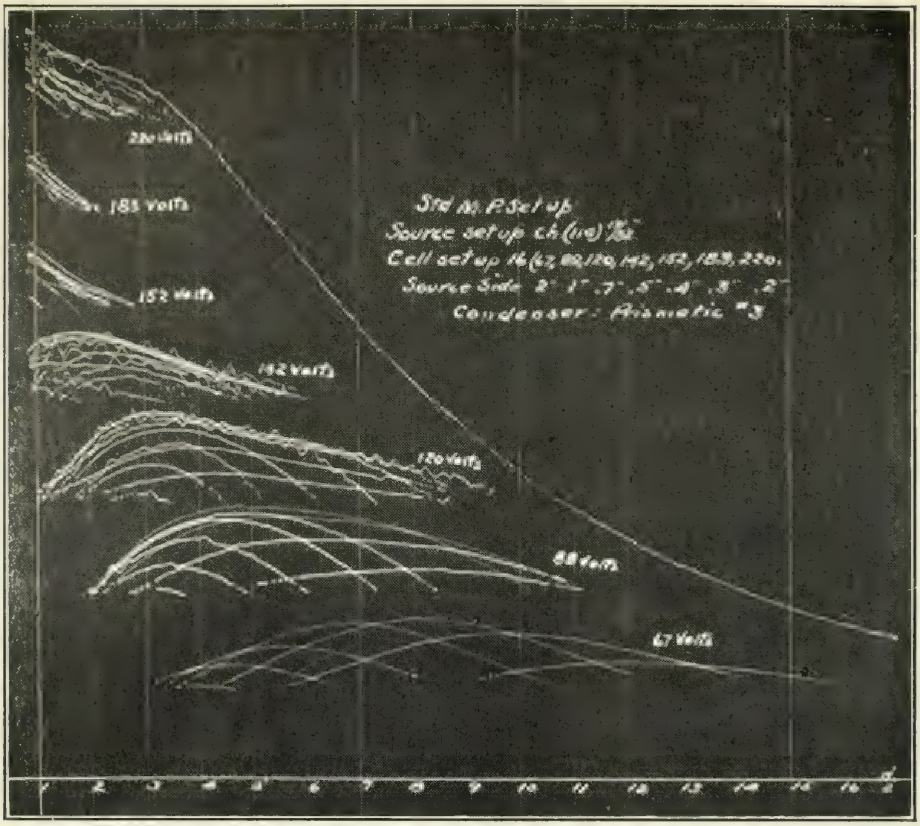

Fig. 9.—Family of curves with a 1½″ objective.

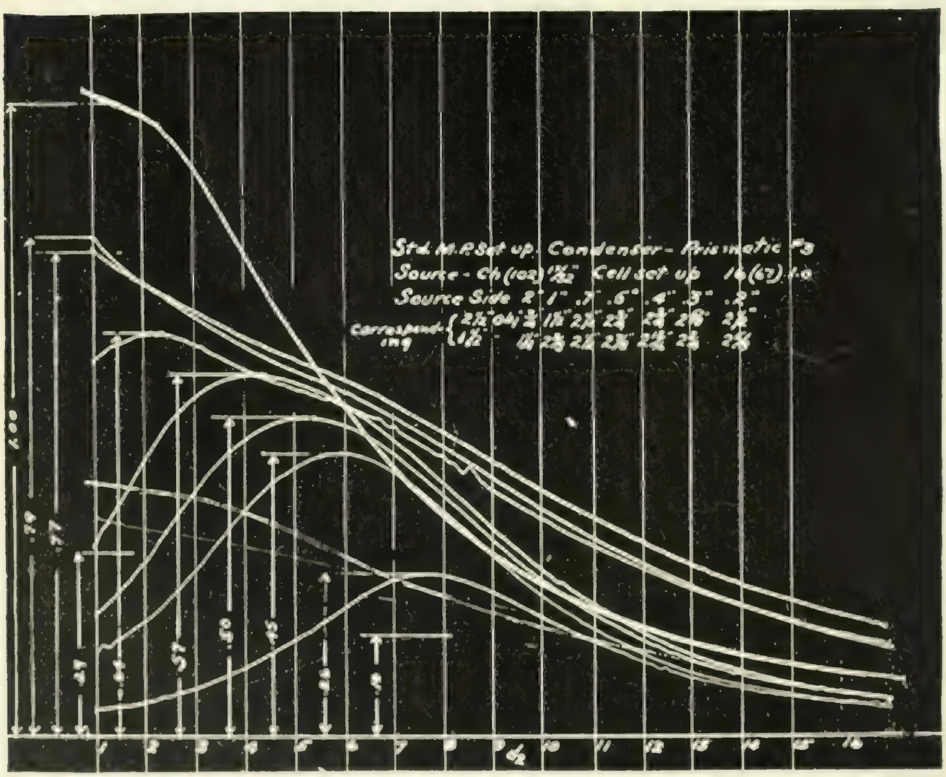

Fig. 10.—Maximum curve of each family of Figs. 8 and 9.

Consider for simplicity a condenser without aberrations. If the aperture plate is at a distance (d_2) from the condenser equal to its focal length, then all rays passing through the center of the aperture F were parallel to the optical axis before striking the condenser. The illumination at F then depends only on rays leaving the source parallel to the axis, and is accordingly independent of the distance (d_1) of the source from the condenser.

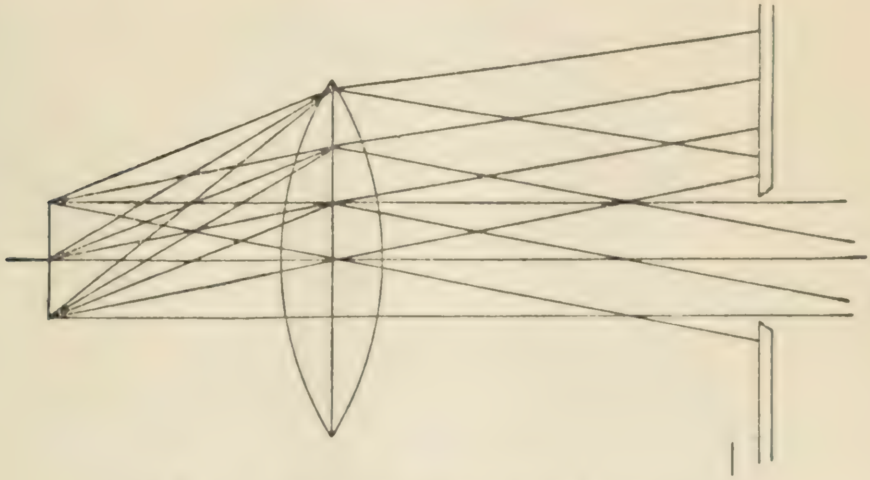

Fig. 11a.—Formation of cones of light rays.

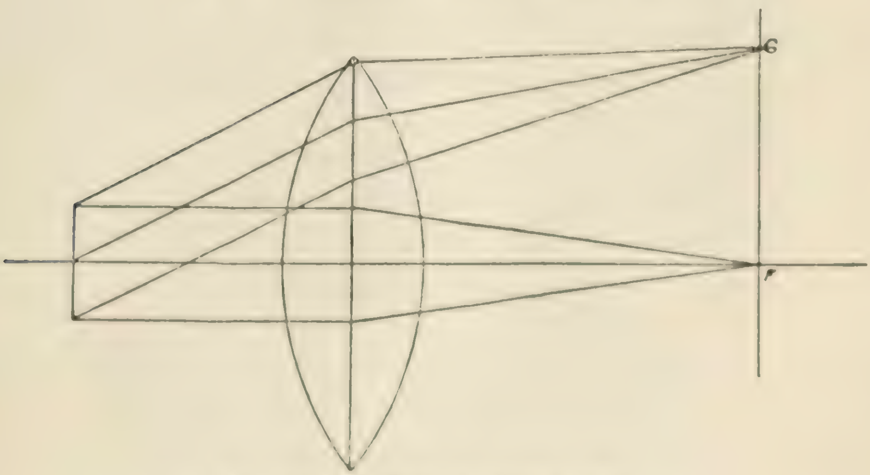

Fig. 11b.—Focusing of parallel rays.

Similarly through points (G) in the aperture plane near F there will pass only rays parallel to each other, but making an angle ("*a*") with the optical axis. If FG is as large as one-half the maximum diameter of the aperture opening we shall get the same quantity of light passing the aperture as we should have if

the condenser were removed and the source put in its place, *i. e.*, put at a distance d_2 from the aperture plane.

If a source of area A′ illuminates a screen of area A″ and distance d away, both source and screen being perpendicular to the line between them and small in comparison to d, then the illumination $L = \frac{B\ A'\ A''}{d^2}$ and for two such systems of the same brilliancy

$$\frac{L_1}{L_2} = \frac{A'_1\ A''_1\ d^2_2}{A'_2\ A''_2\ d^2_1}.$$

The unit quantity of light in Fig. 7 has been assumed to be that falling on a 2½″ objective (A″ = 4.91″) from the aperture ($A'_1 = .616''$) at a distance of 5.5″. Accordingly the light (L_2) falling in the aperture ($A''_2 = .616''$) from a source ($A'_2 = .25''$) at a distance $d_2 = 3.7''$ is

$$L_2 = \frac{.25 \times (5.5)^2}{.491 \times (3.7)^1} \times 1 = .112.$$

From this should be subtracted a 10 per cent. reflection loss, or $L_2 = .101$, and this should be the proportion, obtained at $d_2 = 3.7''$, of the maximum possible illumination. A measurement of the plate (Fig. 7) shows this to be .11—perhaps as good a check as was to be expected considering the assumptions on which the first value was obtained.

We can easily calculate the largest value of d_1 for which the aperture at the focus of the condenser will be completely covered by the spot, of uniform illumination to be

$$d_1 = \frac{d_2\ (D_2 - D_3)}{D_A}.$$

Where D_1, D_2 and D_A are the maximum diameters of the source, condenser and aperature.

All of the light falling on the aperture with the largest of these values d_1 will not, however, pass through even the largest of the objectives considered (2½″).

From the geometry of the set up we see that the largest diameter of condenser that supplies light to the objective is

$$D'_2 = \frac{(D_A + D_3)}{d_3} d_2 + D_A.$$

which with all objectives (D_3) at hand is less than the diameter of the condenser.

Substituting this value of D_2' for D_2 in the formula for d_1 we get

$$d_1 = \frac{d^2{}_2\, D_3}{D_3\, D_A} + \frac{d_2 \left\{ \frac{D_A\, d_2}{d_3} + (D_A - D_1) \right\}}{D_A}$$

and putting in the values $d_2 = 3.7$, $d_3 = 5.5$, $D_1 = .707$ and $D_A = 1.125$ we have the maximum value of d_1 for which the $d_1 =$ constant curve passing through the common point, for the 2½″ objective $d_1 = 9.4''$ and for the 1½″ objective $d_1 = 7.2$. From Fig. 7 these seem perhaps probable values, though as yet no plates have been run to show this.

To save time in determining the best d_1 for each of a number of different sizes of light source, the tops only of each family are photographed. Each curve is marked with a number of breaks to distinguish it from the others of the same family. These breaks are made by momentarily closing the shutter across the slit near the beginning and the end of the curve.

Fig. 8 shows such a family using a prismatic condenser, a 2½″ objective and sources .2″, .3″, .4″, .5″, .7″, 1.0″ and 2.0″ on a side. The larger sources give such a slight increase in the amount of light that the families would normally become hopelessly confused. Accordingly for each successive family such a potential has been selected for the cell as to separate this family from its neighbors. These potentials are indicated in the figure. This illustrates a useful flexibility of the method. The vertical lines were made by flashing the open lamp for motions of the plate in both directions. The failure to check is caused by mechanical inaccuracies of the apparatus.

Fig. 9 shows the families made with the 1½″ objective. The irregularity of the upper curves shows the effect of a high potential on some cells.

Fig. 10 shows the maximum curve of each family of Fig. 8 and Fig. 9 with the value of each maximum in terms of the maximum theoretical limit. Such curves have been made for several condensers,(and it has been shown (loc. cit.) that the introduction of a condenser having slightly greenish or yellowish color, does not

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effect the ratio of galvanometer deflection to the reading on a photometer that depends upon the matching of illumination. In fact preliminary experiments have shown no appreciable variation in this ratio when photometering incandescent lamps running all the way from 2. to .6 w. p. c. Red bulbs, of course, do show a marked falling off in the galvanometer readings for equal illumination as measured by the eye.

The useful application of these curves to actual projection is, of course, subject to the uniformity of illumination. This was determined for each curve by substituting a real objective for the dummy objective (D, Fig. 6), removing the secondary condenser (L) and the cell (P) and throwing an image of the aperture on a screen. For each set-up the value of d_2 was changed and the uniformity of the screen observed directly. Each change in this uniformity and the value of d_2 at which the change occurred was noted. Tracings of the plate curves representing the same set-ups were then made with each curve drawn in in symbols representing the light distribution for all values of d_2. The symbols denote:

————————	Uniformity.
. . . .	Dark corners.
- - - - - - - - - - - - -	Black corners.
o o o o o o o o o o o o o	Dark center.
									Vertical streaks.
|| || || || || ||	Filament image.

Fig. 12 shows the distribution for different values of d_1 when using a plano convex condenser with a uniform source ½″ on a side, such as a 110 amp. d. c. arc. The upper curves are with a 2½″ objective and the lower with a 1¾″ objective.

Fig. 13 is the corresponding tracing for a prismatic condenser used in connection with a 900 watt incandescent filament motion picture lamp, using a 2½″ objective (Fig. 13a) and a 1¾″ objective (Fig. 13b). These three tracings analyze quite completely the projection obtained with the arrangements considered. It must be remembered of course, that the figures denoting maximum illumination are all given in terms of the maximum theoretical limit at the source brilliancy considered. Since the d. c. arc runs at a much higher temperature than the incandescent filament, Fig. 12 and Fig. 13 can not be compared numerically with-

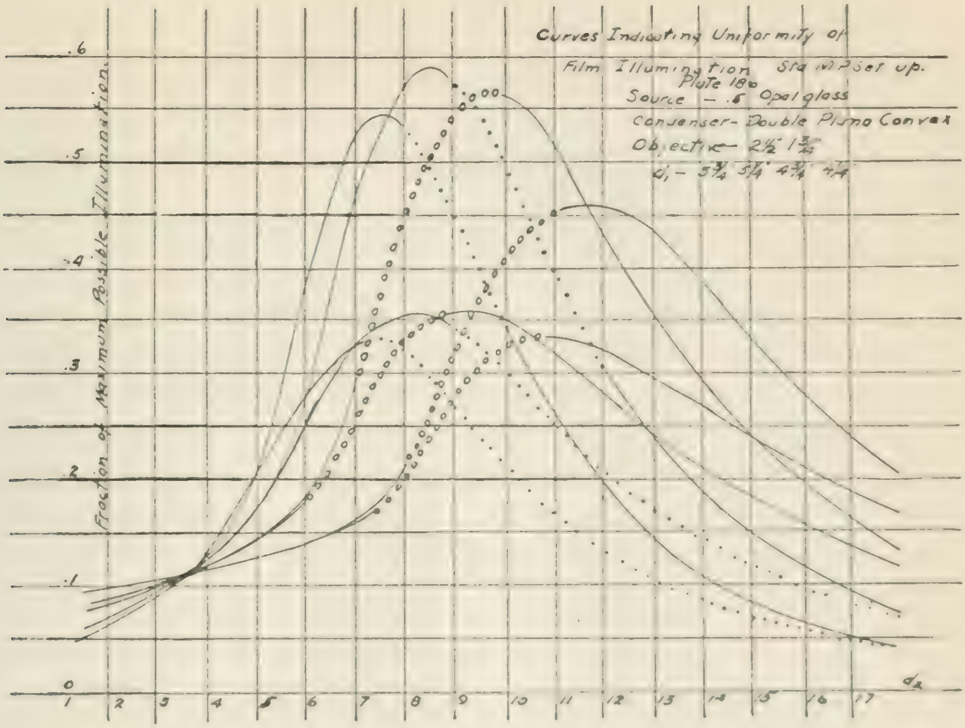


Fig. 12.—Illumination of film.

out the introduction, as a factor, of the ratio of the average intrinsic brilliancy of the arc crater to the average intrinsic brilliancy of the motion picture lamp backed up by its spherical mirror if one is used.

CONCLUSION.

From the experiments above described it would seem that the photo-electric cell offered a valuable means of commercial photometering. Some of its most obvious advantages are:

(1) Freedom from the personal judgment of the operator.

(2) Flexibility of sensitivity over a considerable range by changes in the applied potential.

(3) Possibility of controlling accurately large quantities of energy through the operation of relays by the amplified cell current. The possible applications along this line are numerous.

(4) Automatic registering of changes of illumination with change of some other quantity, such as distance, area, shape, etc.; and even time and potential under certain conditions.

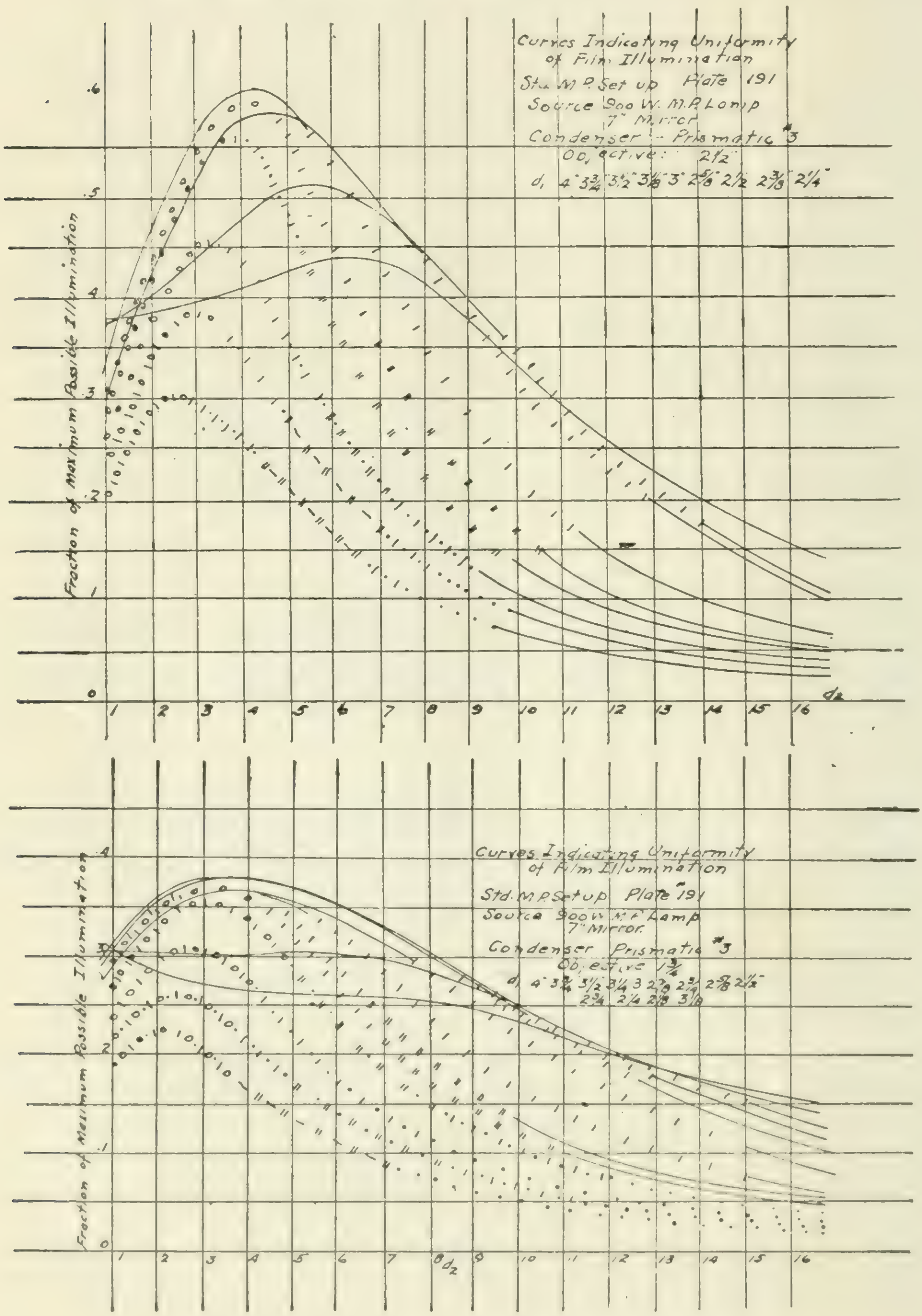
(5) Comparison of lamps without necessity of a constant potential.

The most important limitations of the cell are:

(1) A gradual and as yet not wholly explained change of sensitivity with time.

(2) A color sensitivity differing to a marked degree from that of the eye.

(3) The difficulties of insulation always met with in dealing with very small electrical currents.



Figs. 13a and 13b.—Uniformity of film illumination.

DISCUSSION.

C. H. SHARP: Photoelectricity is something which has been a very fascinating subject to photometrists for many years. Last year at our convention there was a paper on the use of the photoelectric cell in photometry and in that work the photoelectric cell was combined with an amplifier to get the required sensitivity.

We all welcome this further contribution to our knowledge of the cell in photometry. At the risk of appearing ungracious, however, I think I must make the point that Dr. Story has not proven his case as far as the ordinary photometry of incandescent lamps is concerned. He has given us a lot of readings taken with the photoelectric cell. There is no record, however, of the watts consumed by the lamps or of their actual luminous output by which we can judge as to whether his photoelectric cell was doing what he said it was or not. It is a matter of regret that he has not presented those essential data.

I would like to ask Dr. Story as to whether in his judgment, in view of the departure of the cell from the visibility curve of the human eye, he can photometer a lot of lamps which are operating at the same lumens per watt any better from the cell than by measuring the watts. If the lumens per watt are given, all you have to measure is the watts to get the lumens. Or, if the lumens per watt do not need to be exactly constant, over what range of lumens per watt does the cell give photometric results sufficiently accurate for practical purposes?

I would like to know whether the photoelectric cell has any prepondering advantages over a thermal measure, such as a thermopile, used with a filter, giving approximately the normal visibility curve, such as Dr. Ives and others have worked with.

F. E. CADY: The use of the photoelectric cell in practical photometry, as being a different line of attack, is one which all photometrists are interested in. As I remember, a few years ago, when Dr. Ives carried on his extensive investigation, he pointed out that one of the troubles was the difficulty of manipulation. That is in the use of the cell, the actual handling of the cell, and the conditions under which it is used are so much a factor that apparently he was not very strongly in favor of its use in ordinary, practical, every-day photometry. I would like, therefore, to ask

Dr. Story, for the sake of the completeness of the paper, to include in his discussion a description of the type of photoelectric cell which he used, and also something as to how the difficulties of manipulation were overcome, and I refer particularly to those difficulties due to atmospheric conditions, etc.

H. P. GAGE: The work which is here described by Dr. Story has been fully discussed at the Society of Motion Picture Engineers. The difficulty encountered in choosing between condenser systems is that there are an enormous number of variables to be considered. There are the distance from the light source to the condenser, the distance from the condenser to the aperture plate, the diameter of the objective, all to be taken into consideration. The complete range of total adjustments possible for each condenser must be examined before one can decide which is the best condenser.

As these measurements were made to find the maximum amount of light possibly obtainable with each condenser, it did not matter whether the photoelectric cell had the same wave length visibility curve as the eye, a factor of great importance in the photometry of incandescent lamps.

Another useful place for such an instrument would be in determining a very large number of distribution curves across searchlight beams where maximum light intensity regardless of color is of importance.

With this explanation, the usefulness of the photoelectric cell in this connection will perhaps be made clearer to you.

W. E. STORY, JR.: The application of the photoelectric cell to the determinations of the relative illumination of a motion picture screen for different positions of the condenser and aperture is not of course affected by the color-sensitivity characteristics of the cell. As long as the color of the light remains the same the galvanometer deflections will be proportional to the quantity of light and so will indicate the most advantageous arrangement.

A condenser of a yellow hue was found[1] to give with the cell .51 of the maximum theoretical limit. When measured with an optical photometer an average of ten readings showed .52. Of

[1] *Transactions of the Soc. Mot. Pict. Eng.*, May, 1920, p. 110.

course the measurement of the maximum theoretical limit, being obtained without the condenser, is in both methods a measurement of white light. The 2 per cent. difference is probably due to the color of the condenser, as white condensers give closer values by the two methods. However, this difference for lights of materially different hue is so small as to urge the use of the cell for the rough measurements of lamps of the different efficiencies ordinarily met in practice, and for the accurate comparison of lamps with a standard run at about the same temperature. So much of present factory protometry comes under one or the other of these heads that there would seem to be a large field to which the cell might with advantage be applied.

Preliminary tests of lamps at one factory have shown a range of from 2.0 to 0.6 w. p. c. in the consumption of lamps compared by the cell method before the error due to color difference became greater than the mean error of the optical photometer then in use.

The principal difficulty of the method is in getting a suitable rest for the galvanometer. In the ordinary building it will probably be found necessary to place the instrument on a shelf suspended from the ceiling and carefully protected from drafts. In the measurements described in the paper this method of support was found to work entirely satisfactorily. A second source of trouble is, as has been said, a leakage along the insulators. This is particularly bothersome in warm weather. The measurement of small currents always involves these two factors, but they can easily be taken care of under almost any surroundings.

In making the cell the procedure of Kunz was followed.[1] The bulb was silvered inside except for the window and the stem for carrying the anode. The bulb was evacuated and the potassium was then condensed on the silver surface. A little hydrogen was let in and an electrical discharge passed between the cathode and anode after which the hydrogen was pumped out, a little argon admitted and the cell sealed off.

[1] Jacob Kunz, Q. S. T., Nov., 1919.

REPORT OF THE COMMITTEE ON AUTOMOBILE HEADLIGHTING SPECIFICATIONS.*

During the past year the principle of legal regulation of automobile headlighting put forward by this Committee and first adopted by the State of New York in 1918 has received further support through its adoption by the states of Pennsylvania, Connecticut, Maryland and Wisconsin. These states, together with New York and California, are now operating under the regulations as put forth by the Illuminating Engineering Society. Inasmuch as the registration of motor vehicles in these states constitutes roughtly 25 per cent. of the total cars in use in the country, it is evident that the I. E. S. system has made quantitatively very considerable advances.[1] As this is the only proposal now before the public for the systematic classification of automobile headlights into acceptable and unacceptable, and since this system has been endorsed and adopted by states representing such a large proportion of the motor vehicles in use in this country, it would appear reasonable to hope that a basis for very much desired interstate uniformity in automobile headlighting regulations would be found by the universal adoption of the I. E. S. system and specifications. Further consideration of this idea will be given later on in the report.

As was indicated by the report of last year, the specifications originally adopted by the State of New York and subsequently used substantially in their original form by the States of California and Pennsylvania, have been revised in the light of further experience. In their latest form, the form in which they have been adopted verbatim by the State of Maryland, they were published in the TRANSACTIONS of the Society for the current year on pp. 283 to 289. The Secretary of the State of New York has also adopted these specifications for that State, putting them in effect in June of the present year. While this action on the part of the Secretary does not void the approvals which have been issued under the earlier specifications, yet it furnishes a more severe requirement for new devices entering the field, and gives

* Paper presented before the Fourteenth Annual Convention of the Illuminating Engineering Society, October 4 to 7, 1920, Cleveland, Ohio.

[1] Later information is to the effect that the Province of Ontario has adopted the I. E. S. system with the 1920 Specifications.

an opportunity for devices already approved to seek re-approval on the newer basis and thereby to include themselves in what may properly be called a preferred list—a list to which some of the less desirable devices which were acceptable under the old specifications cannot find access.

The status of affairs is summed up in the following table:

State	Specifications	Adopted
New York	I. E. S. 1918 Specifications	June, 1918
	I. E. S. 1920 Specifications in full	June, 1920
California	I. E. S. 1918 Specifications	July, 1919
Connecticut	Modified I. E. S. 1918 Specifications with 1920 limits	August, 1919
Pennsylvania	Modified I. E. S. 1918 Specifications with additional test requirements	July, 1919
Wisconsin	I. E. S. 1920 Specifications (Road tests only)	March, 1920
Maryland	I. E. S. 1920 Specifications in full	June, 1920

CO-OPERATION WITH THE SOCIETY OF AUTOMOTIVE ENGINEERS.

The Lighting Division of the Society of Automotive Engineers having signified to our Committee its desire to propose for incorporation in the Standards Rules of the S. A. E. acceptable specifications regarding headlighting, our Committee at the outset submitted that portion of its specifications which covered the limitations of light in the glare areas as having been determined with a good deal of certainty and as having already been incorporated in state regulations. Reference is here made to the maximum value of 2,400 cp. at a point 100 ft. ahead of the car, 5 ft. above the roadway and of 800 cp. at a point 7 ft. to the left of that point. Before accepting these values a sub-committee of the Lighting Division of the Standards Committee of the S. A. E., in conjunction with several members of the I. E. S. Committee, carried out some verification tests on the road. The analysis of the opinions regarding the glare values of a number of observers participating in these tests gave the following results:

10 observers voted that the glare was excessive.

10 observers voted that the glare was not excessive.

6 observers voted that the glare was the most that should be permitted. In view of these results the practical correctness of

the glare limits as given in the specifications was considered to be confirmed.

It was the view of our Committee that the minimum limitations of beam candlepower which are provided in the specifications for the legal restriction of headlighting would not necessarily apply for the purpose of defining what the S. A. E. wanted, namely, a standard of acceptable performance or recommended practice for new equipment. In other words, specifications governing the performance of all sorts of headlights on the road after deterioration had set in, etc., could not properly represent the standards to be set for new, high-grade equipment. Therefore the records of performance of a large number of headlighting devices as given in the reports made to the various state authorities by the Electrical Testing Laboratories, and by these authorities kindly placed at the disposal of our Committee, were examined by a sub-committee under the leadership of Mr. L. C. Porter with a view to determining what changes could advantageously be made in the specifications to cover the performance which might reasonably be expected from new, high-grade equipment. The results of the deliberations of the sub-committee, after having been considered and approved by our main Committee, were turned over to the S. A. E., by whom they were subjected to a number of practical road trials with various observers, and finally reported to the S. A. E. The Standards Committee of that Society has adopted its proposals as representing their standard for laboratory performance tests of new headlamp equipment. Furthermore, as supplementing their previous adoption of the glare limitations contained in the I. E. S. specifications, they have adopted as an operating requirement the beam candlepower contained in the same specifications. In Appendix A is given an excerpt from the report of the Standards Committee of the S. A. E. covering the above matters.

ENFORCEMENT OF HEADLIGHTING REGULATIONS.

It is evident that the setting up of specifications, no matter how excellent in themselves, cannot accomplish a great deal of good unless headlighting regulations are generally enforced. It must be acknowledged that the improvement in headlighting conditions on the road has not been as great as it was hoped that it would

be. This points to a lack of enforcement rather than to any defect in the regulations themselves. And that there has been a lack of enforcement is denied by no one. It is not possible to locate very closely the blame for this state of affairs. Very often a combination of conditions has been responsible for it. For example, in the State of New York the Secretary of State who makes the regulations for headlighting has no means and no power to enforce his own regulations. In the State of California the headlighting regulations have been attacked on constitutional grounds, and while the constitutionality of the law was in question, no attempt was made to enforce it. Fortunately this difficulty has been cleared up by a sweeping decision of the court which upheld the constitutionality of the California law. It will be recalled that this law incorporates the beam and glare limitations proposed by the I. E. S. and is built around the I. E. S. system of regulation. In other states scarcely enough time has elapsed for any great results to be seen.

A marked exception is to be noted, however, in the case of the State of Connecticut where the responsibility and power to enforce the headlighting requirements is lodged in the hands of Mr. A. L. McMurtry, Chief Inspector of the Department of Motor Vehicles, and member of our Committee, who has made great progress.

The question of enforcement of such regulations is a complex and difficult one, offering new problems, and requiring a great deal of study and some experimentation on the part of those responsible for the enforcement of the law.

There is another feature of the case closely connected with the question of enforcement, which arises from the fact that the public is in general quite ignorant of the true principles and proper practice in headlighting. The adjustment of non-glare devices, which is a matter of fundamental importance, is something of which the users, and also the dealers in such devices, are in a great many casese profoundly ignorant. The motorist very frequently assumes that if he removes his plane glass fronts and puts on a pair of improved front glasses, he has done all that is necessary to make his lights legal and acceptable. Therefore, education of the public in the proper use of these devices is a matter which must go hand in hand with legal enforcement.

The Committee is glad to record that earnest endeavors are being made in various states to instruct the dealers and the public generally in these principles and so to enable the man who is a law-abiding citizen by instinct to conform with the legal requirements in the manner of the light from his automobile.

Furthermore certain special requirements have been written into the laws for the purpose of ameliorating the condition. New York, Pennsylvania and Connecticut will not license cars unless they are equipped with some approved headlighting device, and it is necessary for the motorist applying for a license to show that his car is so equipped. In the State of New York daytime arrests under the authority of the Tower bill, are now being made of owners whose cars are not properly equipped with respect to their headlamps. In the State of Maryland, no headlighting device may be sold unless it has been approved in accordance with the I. E. S. specifications. It is a violation of the law even to have in one's possession a device which has not received approval from the State Board of Motor Vehicle Headlight Inspection, this approval being based on tests made under the I. E. S. specifications. In Wisconsin the manufacturer of each headlighting device must guarantee its compliance with the I. E. S. specifications, but the State will accept as evidence of such compliance a report or certificate showing that the device in question has been approved by another State, or under the new I. E. S. specifications.

OTHER ACTIVITIES OF THE COMMITTEE.

The Committee was called upon by the National Safety Council to aid them in the preparation of a lesson to chauffeurs covering headlight problems. As the time given for the preparation of this material was but three days, it was not possible to call the entire Committee together. However, the members available in New York at the time were assembled, and an outline of such a lesson was prepared and sent to the National Safety Council. A copy of this outline is attached as Appendix B.

The Committee was called upon by the authorities of the State of Maryland to prepare material for the guidance of manufacturers of headlighting devices in preparing adequate and complete instructions for the installation of their devices as required in the revised specifications.

NATIONAL TRAFFIC OFFICERS' ASSOCIATION.

A convention of the National Traffic Officers' Association was held in San Francisco, August 23rd to 27th. The purpose of this convention was to frame a proposal for a uniform traffic law which could be placed before the authorities of the various states for adoption in the hope that by the general adoption of this law uniform traffic regulations would become effective throughout the country. The Chairman of this Committee was invited by the authorities organizing the convention to undertake the guidance of the work of the convention insofar as it related to the lighting question, and by act of the Council of the Society, the Chairman was authorized to undertake this task. Mr. L. E. Voyer, Chairman of the newly organized San Francisco Bay Cities Chapter of the Society, and member of the Committee for the Pacific Coast, co-operated most efficiently in carrying out this work. The formulation of proposals on lighting for the convention was carried out by the following committee of the National Traffic Officers' Association:

J. T. Broderick, Superintendent of Safety Department, Baltimore & Ohio Railroad, Baltimore, Md.

J. J. McRae, Commissioner Police Department, Vancouver, B. C.

F. A. Osborn, State University of Washington.

T. E. Richards, Captain South Park Police, Chicago.

L. E. Voyer, Chairman, San Francisco Bay Cities Chapter I. E. S.

Clayton H. Sharp, *Chairman*.

Fortunately the proposed regulations for incorporation in the model law in regard to headlamps of motor vehicles issued under date of February 11th, 1919, by the I. E. S. Committee on Lighting Legislation and based on the proposals of the I. E. S. Committee on Headlighting Specifications, covered very completely the ground which it was desired that the convention committee should include, and these regulations furnished an adequate basis for discussion. It is gratifying to be able to report that these regulations were adopted by the Headlight Committee of the National Traffic Officers' Association with very trifling alterations and with additions necessary in order to make them com-

plete. Furthermore the Traffic Officers Committee adopted as a basis for the approval of devices under the proposed model law, the rules governing the performance of automobile headlamps on the road and specifications for laboratory tests of headlighting devices for approval by state authorities, as given out by our I. E. S. Committee in its 1920 interim report. The above findings of the Headlight Committee of the Traffic Officers' Association were reported to the Executive Committee of the Association.

Nine other technical committees made corresponding reports covering other branches of traffic regulation. The coordination of these reports and the drafting of a proposed law on the basis of them has been entrusted to a committee which is to report to the Executive Committee of the National Traffic Officers' Association at a meeting in Cleveland in December. The Chairman of our I. E. S. Committee has been appointed a member of this drafting committee. It is greatly to be hoped that the result will be that the National Traffic Officers' Association will adopt regulations which will at least be in close conformity with the I. E. S. recommendations. With the good start which has already been made and with the impetus which can undoubtedly be given the matter of uniform traffic regulations by this body of traffic officers, it may reasonably be expected that the I. E. S. regulations covering headlamps will receive still further endorsement and will eventually form a basis on which practical interstate uniformity will be attained.

Respectfully submitted,

CLAYTON H. SHARP, *Chairman;*
E. C. CRITTENDEN,
L. C. PORTER,
W. F. LITTLE,
G. H. STICKNEY,
PERCY W. COBB,
G. N. CHAMBERLIN,
W. A. MCKAY,
ALDEN L. MCMURTRY,
H. H. MAGDSICK.

APPENDIX A.

S. A. E. Recommended Practice in Headlamp Illumination.

OPERATING REQUIREMENTS.

The headlamps shall be arranged so that under normal conditions of vehicle loading:

1—The light produced on the level surface on which the vehicle stands at a distance of 200 ft. directly ahead of the front of the headlamps and at some point between the level surface and a point on a level with the centers of the lamps shall be not less than 4,800 apparent candlepower.

2—The light produced at a distance of 100 ft. directly ahead of the headlamps and at a height of 60 in. or more above the level surface on which the vehicle stands shall not exceed 2,400 apparent candlepower.

3—The light produced 100 ft. ahead of the front of the headlamp and 7 ft. or more to the left of its axis and at a height of 60 in. or more above the level surface on which the vehicle stands shall not exceed 800 apparent candlepower.

4—The light produced 100 ft. ahead of the front of the headlamp and at some point between the level surface on which the vehicle stands and a point on a level with the centers of the lamps and 7 ft. to the right of the axis of the vehicle shall be not less than 1,200 apparent candlepower.

LABORATORY PERFORMANCE TEST OF NEW HEADLAMP EQUIPMENT.

The combined beam of two headlamps tested under laboratory conditions shall conform to the following limitations when equipped with either a vacuum type lamp of 15 measured mean spherical candlepower or with a gas-filled type lamp of 21 measured mean spherical candlepower at the following points:

A—Directly in front of the vehicle on a level with the lamps.

B—Directly in front of the vehicle one degree below the level of the lamps.

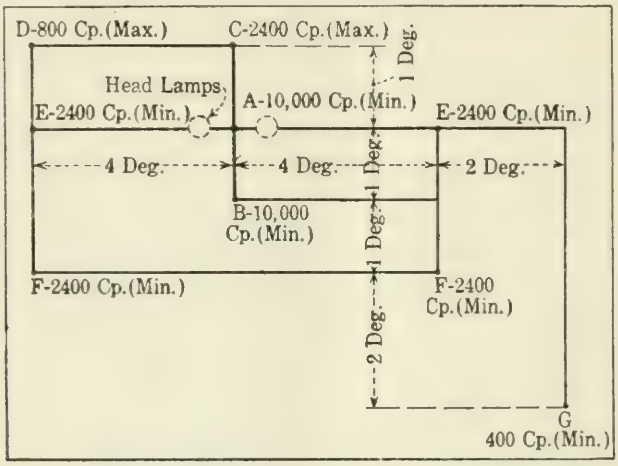
C—Directly in front of the vehicle one degree above the level of the lamps.

D—Four degrees to the left of the vehicle and one degree above the level of the lamps.

E—Four degrees to the right and left of the vehicle and on the level of the lamps.

F—Four degrees to the right and left of the vehicle and two degrees below the level of the lamps.

G—Six degrees to the right of the vehicle and four degrees below the level of the lamps.



Location of Points Specified in Performance Test.

In the above points the limitations shall be as follows:

At points *A* and *B* or at some point between them the apparent candlepower shall be not less than 10,000.

At point *C* the apparent candlepower shall not exceed 2,400 nor shall this value be exceeded at points beyond point *C*.

At point *D* the apparent candlepower shall not exceed 800 nor shall this value be exceeded at points above point *D*.

At or between the points *E* and *F*, both right and left, the candlepower must be at least 2,400 and in the rectangle *EEFF* the candlepower at any point on any horizontal line parallel to *EE* shall be not less than the candlepower at the intersections of such line with the line *EF*.

At point *G* the apparent candlepower shall be not less than 400.

It is desirable that there should not be a sharp cut-off of the light between the points *A* and *C*, but that it should shade off gradually. The candlepower at point *C* should therefore not be much less than the maximum allowed.

It is not intended that these values should be used for the purpose of legal restrictions of headlamps on the road, but should be confined in their application to laboratory tests of new equipment which is in first-class condition and giving its maximum performance.

APPENDIX B.

Submitted to National Safety Council as Lesson to Chauffeurs Covering Headlight Problems.

Dated Sept. 1, 1920.

In general, state laws require that from 30 minutes after sunset to 30 minutes before sunrise no motor vehicle should be operated without sufficient lights; that the tail-light shall be red and visible for a distance of at least 500 ft. and of sufficient illuminating power to reveal the license plate at a reasonable distance, usually taken as 50 ft.

The following are, briefly, the fundamental requirements for automobile headlamps:

1—That when there is not sufficient light to render clearly discernible the road and any substantial object thereon at a reasonable distance, the automobile shall be equipped with two headlamps of substantially equal power, so adjusted and operated as to enable the driver to proceed with safety to himself and other users of the highway under all ordinary conditions of road and weather. This means that the driver must see not only the road directly ahead at a distance of at least 200 ft., but must be able to distinguish objects to the right and left of the car at shorter distances.

2—That this should be accomplished without dangerous or dazzling glare which would blind other users of the highway.

Much experimentation has brought out the fact that the above requirements are reasonable and can be obtained, and furthermore that the minimum limit for road light and the maximum limit for glare can be specified in candlepower, and measured on the road.

The Committee on Automobile Headlighting Specifications of the Illuminating Engineering Society have formulated rules governing the performance of headlights on the road and specifications for laboratory tests of headlighting devices for approval by the state authorities. These specifications were issued and revised May 1, 1920.

Each devise must control the light in the beam and bring it within the requirements for the specified points. The test points and their corresponding location on the roadway are as follows:

TEST POINTS AND THEIR CORRESPONDING LOCATIONS ON THE ROADWAY.

		100 ft. in advance of the car	
Test points	Approximate road locations	Horizontal distance from car axis (feet)	Vertical distance from lamp level (feet)
A	Lamp level directly ahead	0	0
B	Road level directly ahead at 200 ft.	0	1.75 (below)
C	Eye level directly ahead at 100 ft.	0	1.75 (above)
D	Eye level 7 ft. to the left at 100 ft.	7 (left)	1.75 (above)
E	Lamp level 7 ft. to the right at 100 ft.	7 (right)	0
F	Road level 7 ft. to the right at 100 ft.	7 (right)	3.5 (below)

The candlepower requirements at these points with 15 and 21 candlepower lamps, vacuum and gas filled respectively, are:

Test points	Apparent candlepower
A or B (minimum)	4,800
C (maximum)	2,400
D (maximum)	800
E or F (minimum)	1,200

Connecticut, Maryland, New York and Wisconsin have adopted these limits. Pennsylvania and California have made exceptions as follows:

	Apparent candlepower	
Test points	Penn.	Calif.
A or B (minimum)	1,200	1,200
E or F (minimum)	800	No requirements

Approvals may also be issued for devices with incandescent lamps of less than the standards mentioned (15 candlepower vacuum and 21 candlepower gas filled).

The various state laws limit the maximum candlepower allowable with any device as follows:

	New York Conn.	Calif. Maryland Penn. Wisconsin
Maximum candlepower of lamps allowed	24	32

Standard focal adjustments have been adopted as follows:

Focal adjustment No. 1. Filament center at reflector focus—without device reflector produces at a distance of 25 ft. or greater, smallest spot of light.

Focal adjustment No. 2. Filament behind reflector focus—without device reflector produces at a distance of 25 ft. or greater, the largest spot of light without a dark or shaded center.

Focal adjustment No. 3. Filament center slightly behind reflector focus—without device reflector produces a beam slightly larger than No. 1 and smaller than No. 2.

Focal adjustment No. 4. Filament center ahead of reflector focus. Without device reflector produces at a distance of 25 ft. or greater, the largest spot of light without a dark or shaded center.

Important points are:

1. Equip headlamps with approved device taken from list issued by your state or states whose list was issued under the 1920 specifications of the Illuminating Engineering Society.
2. Accept no device not accompanied by full and adequate instructions for installation.
3. Install lamps no higher in candlepower rating than permitted for that device.
4. Focus the lamps as specified in the instructions accompanying the device.

For devices requiring the No. 1 focal adjustment. Move the incandescent lamp backward or forward until the beam has the smallest spot of light on the vertical surface at a distance of at least 25 ft.

For devices requiring the No. 2 focal adjustment. Move the incandescent lamp backward or forward until the beam has the smallest spot of light at a distance of 25 ft. or greater; then move it backward until a dark spot appears in the center of the beam; then move it forward just enough to cause the dark spot to disappear.

For devices requiring the No. 3 focal adjustment. Move the incandescent lamp backward or forward until the beam has the smallest cross section at a distance of 25 ft. or greater; then move the incandescent lamp until a dark spot appears at the center of the beam; then move the incandescent lamp forward until the diameter of the beam

is intermediate between the first obtained and that subsequently obtained.

For devices requiring the No. 4 focal adjustment. Move the incandescent lamp backward or forward until the beam has the smallest spot of light at a distance of 25 ft. or greater; then move the incandescent lamp forward until a dark spot appears at the center of the beam; then move it backward just enough to cause the dark spot to disappear.

5. Aim the headlamps as specified in the instructions.

How to Aim. With the car fully loaded on a level surface and the lamps directed toward the light colored surface at least 25 ft. away from which the beam may be seen (a sheet of white paper may be made to answer), make the following adjustments:

With the front glass removed and the lamps properly focussed as given above, *for devices requiring horizontal beam* adjust the headlamps so that the center of each of the beams as seen on the screen is the same height above the floor or road surface as the center of the lamps.

For devices requiring a tilted beam adjust the headlamps so that the center of the beam of each headlamp as seen on the screen 100 ft. away is . . . . . ft. (tilt in feet called for in the instructions) nearer the floor or road surface than the center of the lamp. If the screen is less than 100 ft. the drop of the beam must be correspondingly reduced.

6. *Home-made device.* Substantial compliance with most of the state laws may be insured without the purchase of special or patented light controlling devices. Probably the best and most efficient home-made device is that which has half of the front glass covered with an opaque material such as paint or paper. This method cuts off half the light but still complies with the specifications issued by the Illuminating Engineering Society. The adjustment is made as follows:

With the upper half covered, use focal adjustment No. 2 and horizontal beam; with the lower half covered,

focal adjustment No. 4 and horizontal beam. The spot of light at a distance of 25 ft. or greater will appear semi-circular with a flat top.

GENERAL.

No device will give the desired results unless the lamps (bulbs) are properly focussed and the beams of light are properly aimed.

In general the road light from the ordinary lamp (bulb) and parobolic reflector headlamp with clear front glass is not satisfactory or safe, and whether or not the use of approved non-glare devices is required in your state, it is advisable to use some form of non-glare device which limits the upward spread of the beam and increases the side spread.

Car vibration often changes the tilt and focal adjustments; frequent checking up of aiming and focal adjustments is necessary.

Spot lights are not essential for driving purposes when good headlamps and light controlling devices are used. Therefore, if spot lights are used the beams should not be projected to the left center of the highway nor more than 50 ft. in advance of the car. (Some spot lamps are equipped with safety devices preventing them from being pointed above the roadway at a distance of 50 ft. ahead to the left of the car axis.)

Always carry spare bulbs of proper candlepower for the headlamps, the same as a spare tire.

The headlight lens may loosen and rotate in the frame; inspect it frequently and adjust and tighten it if necessary.

Reflectors need careful attention:

1. Replace dented reflectors.
2. Replace or re-plate tarnished or rusted reflectors.
3. Finger prints reduce the efficiency of the reflecting surface. Use a soft cloth when handling; and when replacing a bulb do so by covering the hand with a cloth to prevent marring the reflector.
4. When wiping or polishing the reflector use a soft cloth and wipe from the center outward to the rim, not round and round.

If a lens breaks, cover the reflector at once with a cloth or paper and replace the lens as soon as possible with clear glass, if necessary using the home made expedient.

APPENDIX C.

Maryland's Notice to Applicants for Inspection of Headlighting Devices—Dated June 8, 1920.

This Board has ruled that each pair of automobile headlighting devices tested for approval and placed on sale in the State of Maryland must be accompanied by adequate printed instructions of the manufacturer for their proper installation. The following contains a series of suggestions for the assistance of manufacturers in drawing up such instructions; each manufacturer must choose the particular cases which apply to his device, but in all cases points I, II and III should be covered.

INSTRUCTIONS.

With the car full loaded on a level surface and the lamps directed toward a light colored surface at least 25 ft. away on which the beam may be seen (a sheet of paper may be made to answer), make the following adjustments:

I. Aiming.

Remove the front glasses and adjust the bulb so that the spot of light on the screen from each lamp is as small as possible.

For Devices Requiring Horizontal Beam.—Adjust headlamps so that the center of each of the beams as seen on the screen is the same height above the floor or road surface as the centers of the lamps.

For Devices Requiring a Tilted Beam.—Adjust the headlamps so that the center of the beam of each lamp on the screen 100 ft. away is   ft. nearer the floor or road surface than the centers of the lamps. If the screen is less than 100 ft., the drop of the beam must be correspondingly reduced.

II. Focal Adjustment.

Without any front glass observe each beam separately on the screen.

(Note: The adjustments are the same as given in Appendix B.)

III. Attach the device and check up on the screen to see that the beam falls chiefly below the horizontal.

NOTE: When any manufacturer has more than one device, each device submitted for approval must bear a distinctive designation and the approval will cover only exact copies of this device when submitted. In the case of any variation from the exact copy, a new name or type designation must be given and prominently indicated on the device either by means of a letter stamped or moulded in it or otherwise.

DISCUSSION.

JOHN A. HOEVELER: One feature of Dr. Sharp's very complete report which should be emphasized is the matter of education of the public, of the garage man and the enforcing officials. When the Wisconsin law was put into effect, there was a grand rush on the part of motorists to equip the cars with some sort of device, and possibly 85 per cent. of the motorists did that, but the condition wasn't improved much on account of lack of appreciation of adjustment. A man was then sent to some 35 cities in the state to give lectures and demonstrations, and visit the garage people and show them how to make adjustments. After which there was a marked improvement. Furthermore, the same man went out with the police officers—in Wisconsin the enforcement of law is entirely with the police department—who would select the car they thought was violating the law, and our man would make the test.

I believe a great deal of educational work must be done to get good compliance with the automobile headlighting law. I think the Society should undertake to do some of that work, and I believe it would be a very fine thing if the Committee on Automobile Headlighting Specifications would now direct its efforts in that direction. The specifications are complete, and I think are entirely satisfactory.

J. R. CRAVATH: I don't think that the report of the Committee as concerning the specifications needs any defense. If it does need any defense, I would like to state that the tests on which these figures are based were made under actual driving conditions on the road.

The particular point I wanted to call attention to in connection with the enforcement of headlighting law and the securing of observance of these specifications is this: to begin with, proper reflectors and proper devices must be had which can be made to conform with these specifications.

Now, this may be a purely mechanical problem, but nevertheless it is vitally important to our final results, and until we can get automobile manufacturers to put on devices which make a readjustment of the pointing of the beam of light easy, we are going to have a good deal of trouble in getting law enforcement.

GEORGE G. COUSINS: Certain headlamp lenses are so designed that the beams emerging from the top of the headlamps are diffused and scattered and the diffusing parts of the lenses seem to redirect some of the light back to the reflector in such a way that a broad band of light is projected vertically through each beam. When tested at the point C they will pass with considerable latitude, whereas, if the beams are swung horizontally until the center of one comes to the point C on the screen some of these will go considerably beyond the limit. This type of device gets through when tested strictly in accordance with the specifications and yet may cause considerable glare.

G. H. STICKNEY: As a relatively inactive member of the Committee on Headlighting Specifications, I desire to express my admiration for the work they have done and the way they have carried it through simply as a public service. They have met pretty heavy opposition from commercial interests and, of course, some sincere difference of opinion. As far as I can see, they have overcome all opposition except from such interests. Many in the beginning of the work did not understand what the Committee was trying to accomplish, and couldn't see why anybody should fight so hard simply for ideals.

I have learned a good deal about the problem in talking of it with others, both members and non-members, and have observed the remarkable road tests which have been so extensively run. The Committee knows that it hasn't eliminated glare and does not expect to do so entirely, because it is practically impossible. Driving on the road with an occasional glare doesn't cause much

trouble, but a persistent glare does. A diffusing headlight, so far as I have been able to observe, is a misnomer. It is a spread headlight, not a diffusing headlight. I can't conceive of light emanating from some circle less than a foot in diameter, as having any great element of diffusion. It can either be spread or concentrated. A spread light is unquestionably better to drive by, but hard to meet as the glare is everywhere. There are certain average positions where light is absolutely objectionable. You can't keep the light out all the time. Deflection seems to be the best expedient so far discovered. With such an arrangement the glare can be practically eliminated except when passing over a convex section of road and that is a relatively small part of the time. Using such a headlight I have driven through some pretty bad roads in the mountains, and I found no difficulty in seeing, and I have found that I did not get very much objection from those who were meeting me on the road.

C. H. Sharp: I agree with Mr. Hoeveler that the efforts of the Committee should be directed toward educational work of users and those who adjust headlighting devices.

Mr. Cravath pointed out the very great necessity for better lamp supports, supports that can be adjusted, as they should be. He didn't mention something which I know we all appreciate, the need for general better construction of headlamps. Nothing has more clearly emphasized the backward state of the art of constructing headlighting equipment in general than the remark made about the bad engineering.

Now, as a society, we are interested in illuminating results. What we have been trying to do is to treat this problem as illuminating engineers would treat any other problem.

What do we do? We try to place the light which we have available where we want it, and keep it away from the places where we don't want it. We try to utilize it and not waste it. We try to see that it is put on the road and that as little is allowed to be projected into regions where it will produce glare as is consistent with the necessity of some light in those regions to enable a driver to proceed with safety at reasonable speed, and, as a result of practical experiments, to define numerically the candle-power limits, plus and minus, which may serve as a basis for

systematic control of headlights by legal authorities on the one hand or as a guide to a really acceptable solution of the problem on the other.

I don't think that, as a Committee of Illuminating Engineering Society, we ought to interfere in matters of construction in the automobile industry. That may be the function of the S. A. E.

H. H. MAGDSICK: I agree with Dr. Sharp that the correction of the voltage conditions which Mr. Karg and I have outlined lies directly with the automotive engineers rather than with the Illuminating Engineering Society. We presented what we had found with regard to these conditions to this Society for the information of the large number of its members who are interested in bringing about proper headlighting practice. The recommendations of this Society with reference to automobile lighting should take these conditions into account; furthermore, the influence of its members can do much toward a reduction of this variable.

NOTE.—The report was also discussed by Mr. J. J. Engel, to whom his manuscript was returned for revision in order to render it suitable for preservation in the TRANSACTIONS. The manuscript not having been revised and returned as required by the Constitution, his discussion has been omitted.

GENERAL SECRETARY'S REPORT FOR THE FISCAL YEAR 1919-1920.

CLARENCE L. LAW.

The fourteenth year of the Society's history has progressed with the usual interest and enthusiasm on the part of its officers and membership, but the post war revival of the Society's work has not been all that was anticipated, probably because of the magnitude of the plans. The year has been notable chiefly for an ambitious and comprehensive plan for a large increase in the scope of the Society's work and membership, including a plan for a membership drive, calculated to make this program possible. These plans which are in abeyance at the present time will be described more fully in another part of this report.

This administration has been responsible for instigating principally three activities.

The first was that of the Educational Committee which has undertaken to prepare and distribute courses on lighting. These courses will be sold to educational institutions, central stations, and others interested in lighting matters. Inasmuch as there was a considerable amount of detail in the preparation of this work, the results were necessarily delayed and will be given in the Educational Committee's report.

The second activity was that of increasing the membership so that it would include the great majority of those interested in the lighting art both from the standpoint of production and distribution of gas and electric service and all the other elements which enter into its use.

Third, the dissemination of the knowledge of illuminating engineering by representatives of the Society through its Reciprocal Relations Committee, to all organizations engaged in industries where both natural and artificial light is used.

All these plans are now beginning to develop and show indications of being carried out to the end that the Society's future is well assured. It needs, however, the active support and enthusiasm of each individual member in order to bring these plans to a complete success.

COUNCIL.

The Council has met regularly each month with the exception of the summer months, when the Executive Committee which met in July, August and September transacted the necessary business. The attendance of the officers of the Society at Council meetings has been all that could be expected, all officers having attended one or more meetings, some being at each meeting.

MEMBERSHIP.

The status of the membership at the present time, while better than a year ago when viewed from a progressive standpoint, is not increasing in the ratio we have a right to expect, and a membership drive of considerable proportions is really necessary to assure to the Society its position as an important national body.

The low point in membership was reached last year. The accompanying diagram, Figure 1, shows the membership totals

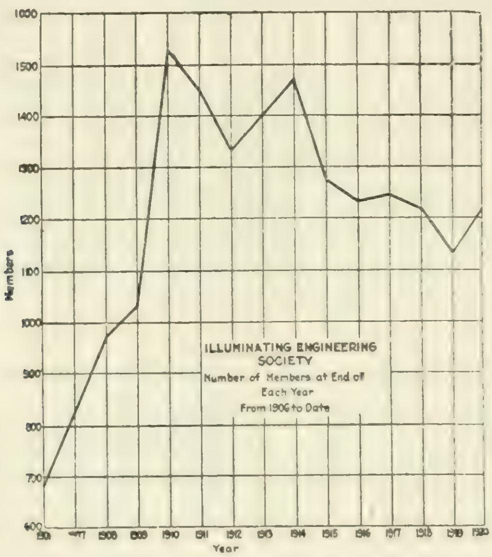


Fig. 1.—Variation in membership of the Society since organization.

year by year in the Society. Figure 2 is a map showing graphically the distribution of membership and indicates that in 1919 the Society had only sixty-four members West of the Mississippi River, and only nineteen South of the Mason Dixon line, the Society's principal activities being confined to the Eastern and Central states. Turning to Figure 3 the situation in 1920 shows marked improvement, there are one hundred and fifty-nine members West of the Mississippi River. (As of October first). This

1919

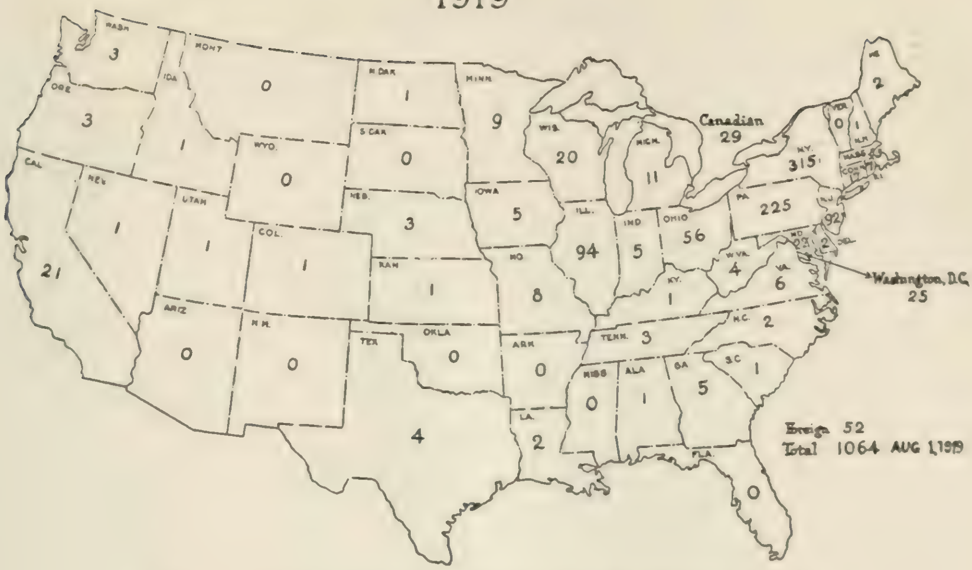


Fig. 2.—Geographical distribution of membership in 1919.

1920

Fig. 3.—Geographical distribution of membership in 1920.

increase is mainly due to the establishment of the first Local Chapter at San Francisco.

Table I, comparing the year 1920 with 1919 discloses a net gain of eighty-six members. The number of new members elected exceeds that for any other year subsequent to 1913, while the number of members dropped is less than for any year in that period. The figures for each year from 1914 to 1920 are given in Table II.

TABLE I.

AS OF OCTOBER 1, 1920.

	1919	1920	
Members and Associates resigned..........	83	60	
Members and Associates dropped for non-payment of dues..........................	85	79	
		1	Cancellation
Deaths	16	6	
Total decrease	184	146	
New Members and Associates elected......	80	223	
Number of reinstatements.................	14	9	
Total net gain...........................	—	86	
Number of transfers from Associates to Members	6	20	
Sustaining Membership	64	58	

TABLE II.

YEAR ENDING OCTOBER 1, 1920.

	Total members	New members	Members dropped
1914–1915	1,472	161	342
1915–1916	1,271	121	155
1916–1917	1,237	169	148
1917–1918	1,258	150	187
1918–1919	1,221	93	185
1919–1920	1,129	232	146
Balance 10/1/1920..........	1,215		

SUSTAINING MEMBERS.

The present number of Sustaining Members is fifty-eight against sixty-four at the beginning of the administration. Four resignations were accepted in 1919 and two in 1920. In accordance with a recent Constitutional Amendment doubling the maximum dues which may be paid by Sustaining Members, several of the larger Manufacturing Concerns have already arranged to increase their dues, some by one hundred per cent. It is earnestly recommended that during the coming year the Membership Committee make a strong effort to enlarge this class of membership as the revenue from this source represents about fifty per cent. of our income. Individual co-operation is very necessary to progress in this direction.

LOCAL REPRESENTATIVES.

The Local Representatives of the Society now number thirty-eight, representing twenty-three states (see circles shown in Figure 3). There are also representatives in various cities, in Canada, South Africa and Australia. The number of Local Representatives is significant. It has increased to this number from the little nucleus of nine at the end of the fiscal year 1914-

1915. These Local Representatives offer an entering wedge for the beginning of Society activities in outlying districts away from our established sections and should be the forerunners of Local Chapters of the Society which we hope to establish in a great many of the larger cities.

TABLE III.

City	1920 Population	City	1920 Population
New York	5,621,151	San Antonio	161,308
Chicago	2,701,705	Dallas, Tex.	158,976
Philadelphia	1,823,158	Dayton, Ohio	152,559
Detroit	993,739	Bridgeport, Conn.	143,152
Cleveland	796,836	Houston, Tex.	138,076
St. Louis	772,897	Hartford, Conn.	138,036
Boston	748,060	Scranton, Pa.	137,783
Baltimore	733,826	Grand Rapids, Mich.	137,634
Pittsburgh	588,193	Paterson, N. J.	135,866
Los Angeles	576,073	Youngstown, Ohio	132,358
San Francisco	508,410	Springfield, Mass.	129,563
Buffalo	506,775	Des Moines, Iowa	126,468
Milwaukee	457,147	New Bedford, Mass.	121,217
Washington	437,571	Fall River, Mass.	120,485
Newark, N. J.	414,216	Trenton, N. J.	119,289
Cincinnati	401,247	Nashville, Tenn.	118,342
New Orleans	387,219	Salt Lake City, Utah	118,110
Minneapolis	380,582	Camden, N. J.	116,309
Kansas City, Mo.	324,410	Norfolk, Va.	115,777
Seattle	315,652	Albany, N. Y.	113,334
Indianapolis	314,194	Lowell, Mass.	112,759
Jersey City, N. J.	297,864	Wilmington, Del.	110,168
Rochester	295,850	Cambridge, Mass.	109,694
Portland, Ore.	258,288	Reading, Pa.	107,784
Denver	256,491	Fort Worth, Tex.	106,482
Toledo	243,109	Spokane, Wash.	104,473
Providence	237,595	Kansas City, Kan.	101,177
Columbus	237,031	Yonkers, N. Y.	100,226
Louisville	234,981		
St. Paul	234,595	Schenectady, N. Y.	
Oakland, Cal.	216,361	Lynn, Mass.	
Akron, Ohio	208,435		
Atlanta	200,616	CANADA	
Omaha	191,601	Toronto	
Worcester, Mass.	179,754	Montreal	
Birmingham, Ala.	178,270	Quebec	
Syracuse	171,717	Winnipeg	
Richmond, Va.	171,667	Vancouver	
Memphis, Tenn.	162,351		

Cities in the United States, which according to the latest census report, have a population of one hundred thousand or more are listed in Table III. There are sixty-seven of this class and besides these there are many more cities of lesser population where there is considerable interest in our Society's work.

There are also five cities in Canada coming under the latter classification. In all there are perhaps one hundred cities in the United States and Canada where it is possible to proceed with the establishment of Local Chapters of this Society, with the logical assumption that each chapter could produce an average new membership of, say fifteen, thus providing possibilities for a total of fifteen hundred new members by simply stimulating organized local activities. Such a program would entail little or no cost to the Society providing earnest co-operation could be obtained from the travelling representatives of the larger manufacturing interests concerned in the work of the Society. This might be accomplished by having several members meet such travelling men in a certain city at which time a Committee of Local Representatives might be formed to continue the organization work. There would be no additional expenses to these travelling representatives by reason of such a program.

PLANS FOR INCREASING THE MEMBERSHIP OF THE SOCIETY.

In the tables previously shown, Membership in the Society has been compared year by year. Table IV shows a comparison of membership turnover for the past six important national Socie-

TABLE IV.

Society	Total	New members	Total dropped	
Mechanical	11,882	1,700	250	(includes 88 deaths & 68 resignations)
Natl. Elec. Light Assn.	10,498	3,704	3,362	
Electrical	10,352	1,411	311	(includes 82 resignations)
Civil	9,408	687	122	(includes 36 resignations)
Mining & Metallurgical	9,053	1,600	333	(includes 83 resignations)
Illuminating	1,215	232	146	(includes 6 deaths & 60 resignations)

ties, including our own, and indicates that our growth could be stimulated wonderfully by a systematic and continuous effort to strengthen the Society numerically. There is a plan under consideration for accomplishing this increase and the Council during

TABLE V.

Members of organizaiions or individuals who might join or contribute one or more members to Illuminating Engineering Society	Classification of industry
1,200	Gas Central Stations
6,500	Electric Central Stations
24,000	Manufacturers of Incandescent Lamps and Selling Agencies
500	Manufacturers of Gas Incandescent Lamps and Dealers
700	Fixture Manufacturers and Dealers
300	Glassware Manufacturers and Dealers Electric Light Appliance Manufacturers and Dealers Metal Reflector Manufacturers
50	Electric Sign Manufacturers and Dealers
5	Manufacturers of Searchlights and Searchlight Equipment
5,000	Industrial Plants
30	Engineering Societies
1,500	Consulting Engineers
7,000	Architects
1,200	Municipal Engineers
25	Trade Journals
150	Manufacturers of Farm Lighting Equipment Manufacturers of Lighting Equipment of Automobiles
4,000	Electrical Contractors
10	Daylighting Devices
30	Paints
500	Interior Decorators
500	Ophthalmologists
1,200	Educators
300	Governmental and State Employees on Illumination Work
200	Railroads
100	Motion Pictures
2,000	Large Mercantile Establishments
1,000	Office Buildings, Museums, Art Galleries, etc.
58,000	Total

the past year has been working, so to speak, on a foundation capable of carrying the large superstructure we hope will be erected. We wish the public to know our Society better and to benefit by that knowledge. In this connection it has been proposed by President Doane that a series of technical bulletins be issued under the joint auspices of a proposed new Committee on technical publicity and the Committee on Papers, these bulletins to be underwritten and purchased for general distribution by Sustaining Members. The proposition has aroused considerable interest and is being very carefully considered. The Committee on Education has also made some progress along these lines in the development of an extension course in illumination for use by those who are connected with the lighting industry and a definite plan has been made, (which the Council has approved,) for publishing a series of lessons.

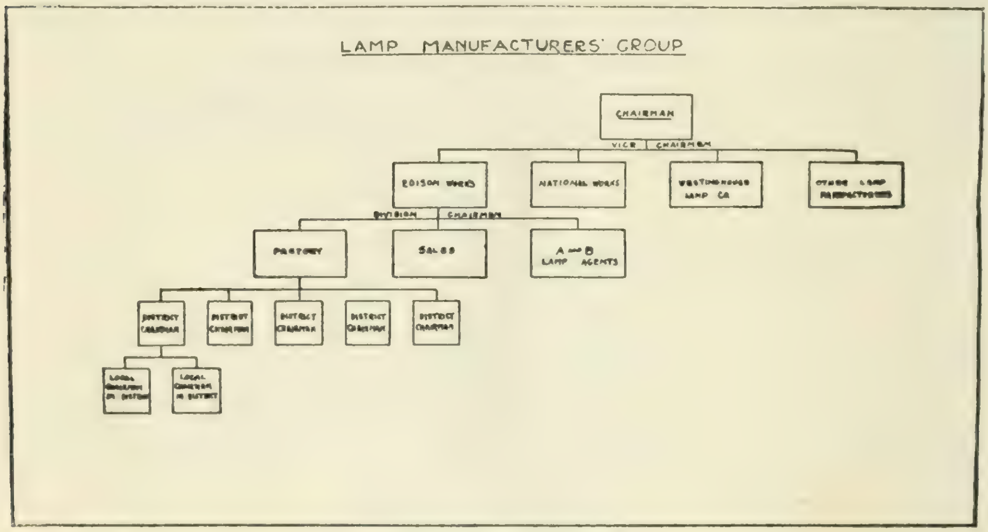


Fig. 4.—Sub-divisions of the lamp manufacturers group.

In order to facilitate consideration of the plan for a membership campaign, we have in Table V classified the industries of the Country as affecting our Society, into twenty-six divisions, giving approximately the number of organizations in each division which might be expected to contribute one or more members to the Society. The staggering total of these organizations reaches fifty-eight thousand, from which a potential list of prospective members would run up to well over one hundred thousand. Therefore to follow the plan used by one of our kindred societies, it would be

necessary for various leading men in each division of industry to co-operate with us by causing to be prepared a list of possible prospects for membership in the Society in each of the divisions listed.

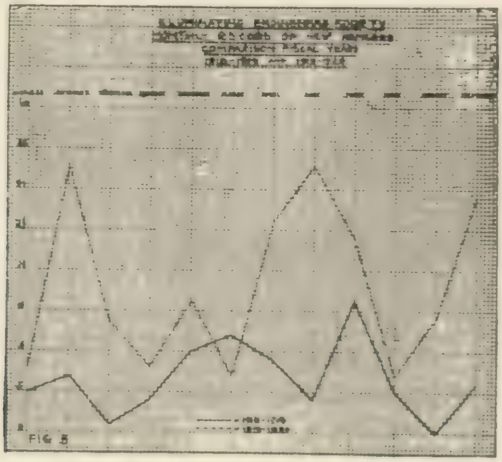


Fig. 5.—Monthly record of membership increase.

Figure 4 illustrates one of the groups of the large Membership Drive Committee which has been considered by the Council, the drive to be intensive for say three weeks and to be carried on by group committees in each classification of industry previously given (in Table IV) and supplemented by publicity in house organs and the technical press as listed. The total personnel of the membership drive committee under this plan might easily reach three or four hundred members and non-members (the latter providing in themselves a nucleus of prospective members).

Figure 5 is a double curve showing the number of new members month by month for the past two years, and indicates that there are months in the lighting season that do not produce new members in the proportion that might be expected.

CONSTITUTIONAL AMENDMENTS.

At the last general election there were adopted four important constitutional amendments which have a direct bearing on the future growth of the Society.

AMENDMENT NUMBER I.—*Student Membership*—This provides for a new grade of Membership to be known as Student Members who may be regularly registered students in an engineer-

ing, technical or fine arts course in any college or university acceptable to the Council. A student member shall have the privilege of participating in meetings and of subscribing to the TRANSACTIONS, at an established cost price, but shall not have the right to hold office, except in a student chapter. A Student Member shall be eligible to continue in that grade for the fiscal year following his leaving college, and shall be eligible for transfer to the grade of associate on request at any time within sixteen months after his graduation.

AMENDMENT NUMBER IIA.—*Associate Membership.*—This lowers the age limit for Associate Members from 21 to 18 years, eliminating formalities previously required and provides that the board of examiners may elect Associate Members reporting those elected to the Council. In short, any person interested in illumination may become an Associate Member of this Society if he so desires.

AMENDMENT NUMBER IIB.—*Affiliates*—Non Members of the Society may affiliate with a section or chapter of the Society in accordance with the regulations adopted by said section or chapter and approved by the Council. Such affiliates may take part in local meetings, present papers and discussions. They may act on Local Committees and contribute to assessments for local use. Affiliates will not be privileged to vote or hold executive office. Thus an individual passively interested in illumination may be held in the organization and his interest quickened by contact with members.

AMENDMENT NUMBER III.—*Increased Membership Dues*—For the past year our dues for members and associates have not been sufficient to meet the Society's expenses because of the rising costs, notably in the case of printing, where the costs have already increased eighty per cent. The Society's membership dues are increased from $5.00 to $7.50 for Associates, from $10.00 to $15.00 for Members, and the maximum for Sustaining Members from $250.00 to $500.00.

AMENDMENT NUMBER IV.—*Local Chapters*—There has been an apparent demand in the Society for local activities in districts remote from our established sections and to meet this demand an amendment providing for local chapters has been passed. Local

Chapters in effect will be miniature sections of which it is hoped that eventually one hundred or more may be established.

ABSTRACTS OF COMMITTEE REPORTS.

COMMITTEE ON PAPERS.

The Committee on Papers has done excellent work during the year just passed. They have collected for presentation a total of sixty-one papers, of which number forty-eight were printed in the TRANSACTIONS.

Papers were presented as follows:—

Chicago Section	6
New England Section	4
New York Section	12
Philadelphia Section	16
1920 Convention	28
	66
Less multiple presentation	5
Total number presented	61

POPULAR LECTURES.

There were three presentations of popular lectures on Home Lighting and one on Store Lighting during the year.

The TRANSACTIONS of the Society have been published regularly, consisting of nine numbers and incorporating the following material.

	1917	1918	1920
Papers with discussion	27	23	36
Addresses	1	1	5
Abstracts	8	18	4
Annual Reports	4	9	3
Pages Society Notes	111	115	124
Paid advertisements	113	110	92
Pages of advertisements	72	72	72

COMMITTEE ON PUBLICITY.

This Committee held two meetings in the past year; one to consider how the Committee could assist in a publicity campaign to advertise the forthcoming membership drive. A list of house organs and trade papers with the total circulation estimated at one hundred and fifty thousand was submitted. It was thought these publications might co-operate in an Illuminating Engineering Society membership campaign with full page publicity. It was

further recommended that special articles on illumination be written by men especially assigned to this work, such articles to appear in the various house organs, the technical and semi-technical press at the same time as the full page publicity (which was to include a coupon application blank to be returned by those interested).

The second meeting of the Committee was devoted to a plan for the standardization of Society publications and recommended, first:—that finances permitting a monthly journal be established providing also that Part II of the present TRANSACTIONS be published annually in bound form immediately after the annual convention.

That a series of technical bulletins covering the various topics in the general field of Illuminating Engineering be arranged for and be revised from time to time as might be considered necessary.

BOARD OF EXAMINERS.

This Committee acting for the Council has carefully reviewed the qualifications of all applicants for membership. The Committee has passed upon a greater number of new applications during the past year than any year since 1914.

COMMITTEE ON ARTISTIC TREATMENT OF INTERIOR LIGHTING.

The Committee is planning to prepare a bulletin showing photographs of particularly handsome installations together with some ideas regarding decorative possibilities and fixtures adapted to the carrying out of such ideas.

COMMITTEE ON THE REVISION OF CONSTITUTION AND BY-LAWS.

The Committee recommended certain Amendments to the Constitution which were recently adopted and are now preparing By-Laws in harmony with these new Amendments.

COMMITTEE ON FINANCE.

The work handled by the Committee on Finance is best shown by the accompanying tabulations, Exhibit A being the Balance Sheet as of Sept. 30, 1920, and Exhibit B the Earnings and Expenses for the twelve months ending on that date.

EXHIBIT "A"

BALANCE SHEET—SEPTEMBER 30, 1920.

Assets

Cash on hand and in bank		$1,195.59
Liberty Bonds		3,000.00
Accounts Receivable—		
Advertising	$ 113.92	
Sustaining Members Dues	10.00	
Members Dues	22.50	
TRANSACTIONS	23.72	170.14
Inventory—Badges and Reprints		306.00
Furniture and Fixtures		578.30
New York Section		27.50
		$5,277.53

Liabilities

Advance Dues	$ 233.15	
Reserve for unpresented items	548.03	
Accounts Payable	2,562.51	
General Electric Company	*2,500.00	$5,843.69
Deficit—		
Surplus October 1, 1919	$5,840.70	
Adjustments	512.90	
	$5,327.80	
Net Loss for the twelve months ended September 30, 1920	5,893.96	
Deficit September 30, 1920		$ 566.16

EXHIBIT "B"

STATEMENT OF EARNINGS AND EXPENSES FOR THE TWELVE MONTHS ENDED SEPTEMBER 30, 1920.

Earnings.

Members Dues	$3,830.00
Associate Members Dues	3,947.50
Sustaining Members Dues	3,930.00
Initiation Fees	325.00
Advertising Sales	922.16
TRANSACTIONS Sales	601.00
Miscellaneous Sales	152.65
Royalties—Illuminating Engineering Practice	59.00
Interest on Deposits	130.01
Interest on Liberty Bonds	110.44
Total	$14,007.76

* Amount loaned by the General Electric Company to the Committee on Education; to be returned.

Expenses.

TRANSACTIONS		$ 6,519.81	
General Office—			
Salaries	$6,752.10		
Rent	1,529.69		
Printing and Stationery	593.70		
Postage	492.28		
Telephone	214.84		
Miscellaneous	536.51	10,119.12	
New York Section		530.35	
Philadelphia Section		356.54	
Chicago Section		381.11	
New England Section		168.51	
Committee Expense		155.99	
Convention 1920		1,333.47	
Miscellaneous Expense		45.00	
Depreciation Furniture and Fixtures		64.25	
Committee on Education		317.57	
			19,991.72
Excess of Expenses over Earnings			$ 5,893.96